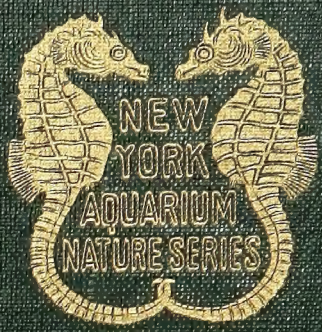

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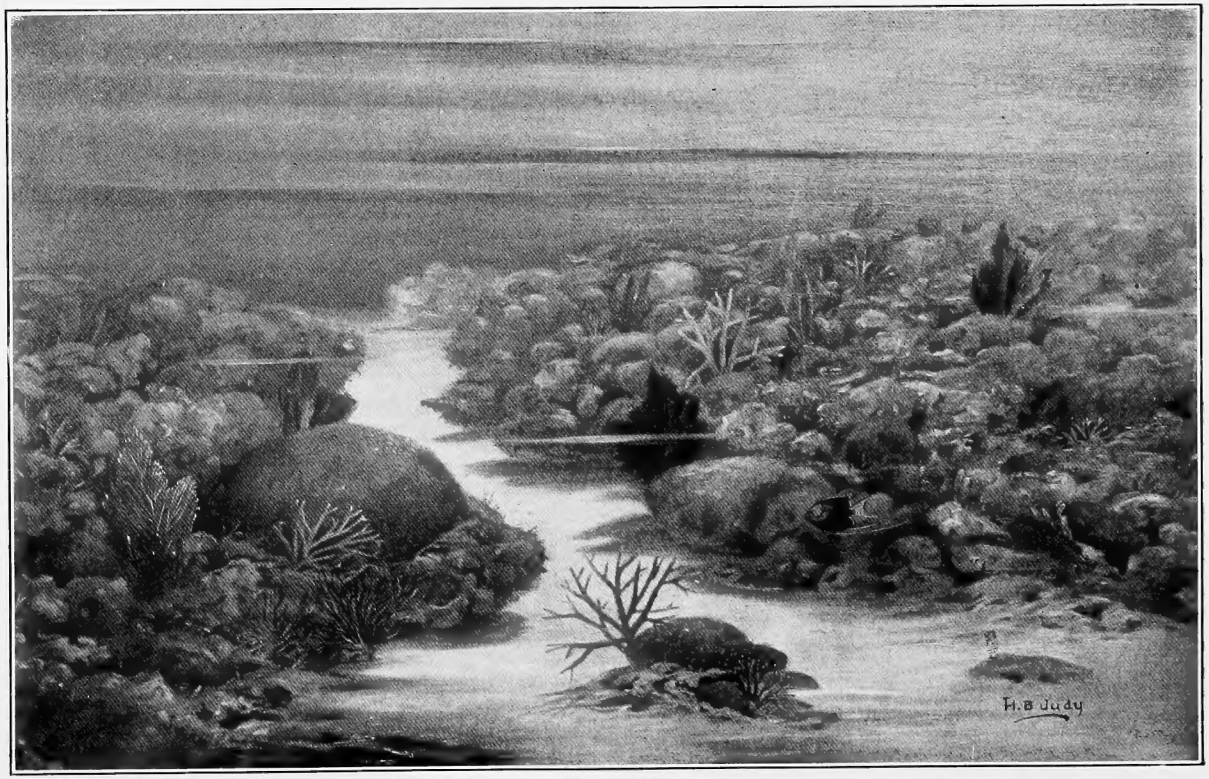

A CORAL REEF OF THE BAHAMAS. From an Oil Painting by Herbert B. Judy.
Exhibited at The Brooklyn Institute Museum.

New York Aquarium Nature Series

SEA-SHORE LIFE

THE INVERTEBRATES OF
THE NEW YORK COAST

BY

ALFRED GOLDSBOROUGH MAYER

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Carnegie Institution at Tortugas, Florida

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ADVERTISEMENT

The present work is the first of the New York Aquarium Nature Series. It is designed chiefly as an aid to the study of the marine invertebrate life of the region about New York. It will be found a valuable reference book for visitors studying the collections of the Aquarium, as the species herein considered are very largely those which may be seen there alive, from time to time. The book is a gift of the author to the New York Zoological Society, and the proceeds from all sales are devoted to the increase of the collections of the Aquarium.

C. H. TOWNSEND,
Director of the Aquarium.

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PREFACE

THIS little work attempts to present in clear, untechnical language, a description, accompanied by photographs, of the larger and more conspicuous marine invertebrates of the coast of New York State. In order to increase the general usefulness of the work, however, accounts of the habits of a few creatures from other regions are introduced. Such are: Commercial sponges, crayfishes, the spiny lobster, the edible shrimp, the orchid land-crab, freshwater mussels, the giant clam, the pearl oyster, the giant squid, and the chambered nautilus A brief description of some of our common "sea squirts," or tunicates, is also given on account of their interesting position among primitive vertebrates.

This work is intended for readers who may be unfamiliar with the technical terms in use among specialists, and consequently such terms have been avoided whenever a simple English equivalent could be substituted.

Its aim is to increase intelligent interest in the habits and life-histories of our marine animals, and to disseminate a knowledge of their appearance and relationships. It is not a textbook of systematic zoology.

It is designed to be of use to the beginner, and with the hope that a perusal of its pages may stimulate to further study, many references to works in the English language of a more thorough

and pretentious character are given. We hope that it may thus serve as a stepping-stone to those whose love of nature may lead them to achieve to that greater delight in her works which can come only through long and thoughtful study of her manifold forms and wonderful ways.

Lastly we hope that these pages may serve to render the collections of the Aquarium, and of the Natural History Museums of New York and Brooklyn more intelligible, and to aid, even if it be but little, in the educational work which it is the high mission of these institutions to perform.

It gives the author sincere pleasure to express his gratitude to the authorities of the Museum of the Brooklyn Institute of Arts and Sciences in allowing him to take photographs of specimens upon exhibition within the Museum.

Of the 119 figures; 111 are derived from photographs of living or dead specimens, while eight are taken from hitherto unpublished illustrations. Of the illustrations; three representing a coral reef of the Bahamas, the giant squid, and the American octopus are from paintings by Herbert B. Judy, Esq. The originals are on exhibition at the Museum of the Brooklyn Institute of Arts and Sciences. Five illustrations are from drawings by the author. Of the 111 photographs of animals; one, that of *Sagartia leucolena* was presented by Mr. William F. Patterson, while the remainder were taken by the author.

NOTE

The present work is the first of the New York Aquarium Nature Series. It is designed chiefly as an aid to the study of the marine invertebrates of the region about New York, but on account of the wide distribution of the species found along our shores it is applicable to the Atlantic coast generally. While it is primarily a book for the seaside, it will be found a valuable reference book for visitors studying the collections of the Aquarium, as the species herein considered are very largely those which may be seen there alive from time to time.

Although the work will be accepted as authoritative from a scientific point of view, having been prepared by a professional zoologist of the highest standing, it is popular in character. It presents the facts of modern zoological investigation so clearly that it will be attractive to the general reader as well as to the nature student and teacher. The illustrations are mostly from photographs taken by the author of living specimens in the New York Aquarium and elsewhere.

The book is a gift of the author to the New York Zoological Society, and the proceeds from its sale are devoted to the publication fund of the Aquarium.

C. H. TOWNSEND,
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INTRODUCTION

NATURALISTS have come to believe that all of the higher animals and plants have descended from simpler forms which lived in the past; and that these in turn were derived from even simpler ancestors. Indeed, it is possible that all animate nature is the offspring of one primitive living cell which contained within itself the power of giving rise to all of the plant and animal life of our world.

But although we know not how or when life originated, science has been able to make known some few of the remarkable changes which have come over animate forms under the influences of evolution, and natural selection.

Excellent examples of such changes are exhibited in the great Hall of Vertebrate Fossils at the American Museum of Natural History, where we may see a series of fossil skeletons which prove that the horse was once a four-toed creature hardly larger than a fox but that now it walks upon its middle toe, the side ones having disappeared. Another series of fossils shows that in Eocene times the camel was also a little four-toed creature; but now there are but two toes on each foot, the side ones having disappeared.

A careful study of living creatures has shown that, while offspring usually bear a close resemblance to their parents, a few depart widely from the parental types, and that some of these departures show a strong tendency to maintain themselves, through inheritance, for generation after generation. But this is not all, for we know that animals and plants tend to increase at a rate so enormous that, should all survive, the land would soon be densely covered and the ocean completely filled with living creatures. This, however, is prevented by the constant competition for life. Only those few that are able to conquer in the strife for food and space can survive, and myriads of the weak and unfit must perish. Whole races have succumbed to this competition. Not one of the

trilobites, more than 1700 species of which existed in the Cambrian and Silurian rocks, survives to-day; and the sea lilies, which once grew in vast colonies along our shores, are now represented by only a few rare species in the deep ocean.

The older naturalists did not realize the vastness of the destruction which this battle for life has wrought, and thought that each species was a separate creation that had existed unchanged since the beginning. We now know that species appear to be distinct one from another because the intermediate forms have died out; and the longer a once closely related group of species has existed, the wider do their differences become until we may look in vain for the "linking forms" which once connected all of them.

For example, we know that the vertebrates are recent, and are descended from the far more ancient invertebrates. Accordingly, we find that there are but few breaks in the chain of forms ranging from the lowest fishes to the mammals. Indeed, the embryos of the highest mammals display gill slits in their necks, which soon close over, but which were of use throughout life in their fish-like ancestors. When we study the invertebrates, however, we find wide gaps so that no one has yet been able to determine the relationships of some of the greatest groups.

For example, we can not tell how the sponges, jellyfishes, echinoderms or worms may be related one to another, but on the other hand we have reason for the belief that crustaceans and insects are descended from worm-like ancestors, and that mollusks may possibly have had a somewhat similar origin.

It is interesting to observe that we meet with the same conditions among plants. The algæ and fungi show wide gaps which prevent one from arranging them in any connected series, whereas the flowering plants, which are certainly more recent and have descended from non-flowering forms, can be arranged in a fairly regular chain, leading gradually from the lowest to the highest.

We must bear in mind, however, that recent studies by Bateson, de Vries and others tend to show that new species may appear suddenly as the offspring of old and well known forms; and that these new and peculiar animals or plants may, through inheritance, perpetuate their new peculiarities. There may then be no intermediate or "linking" forms between the old and the new species.

A large number of marine animals whose true home is among the Bahamas, or West Indies, are drifted upon the southern coast of Long Island by the southerly winds of the summer months and become quite abundant along our shores in August. From November until April, however, the northerly and easterly winds prevail, and these drift down upon us a host of creatures whose home is in the cold arctic water. We see then that tropical and sub-tropical animals are found along our coast in summer and early autumn, while arctic creatures live there in winter and spring. There are, however, an even greater number of creatures which are permanent residents, and are to be found with us in some stages of their lives at all seasons of the year.

Many marine animals or plants thrive only between tides, and must be exposed to the air for at least an hour or two every day. Such are the barnacles, some snails, and the great masses of olive-green seaweed with gas filled cavities in its stems called *Fucus*. Others, such as the brown, salmon-pink, and white sea anemones *(Metridium marginatum)* and the common starfish *(Asterias forbesii)*, delight in the shallow tide-pools but do not thrive if long exposed to the air.

Great numbers of creatures live along the coast beyond the influence of the tides and find their homes among the eel-grass, under stones or mud, or roaming freely through the water.

Others, such as the Portugese man-o-war *(Physalia)*, the beautiful, purple floating snail *(Janthina)*, and a host of jellyfishes and crustaceans find themselves at home far out at sea and never come near land unless drifted along the coast by accident. Such are the creatures which even thousands of miles from land cause the ocean to glisten with brilliant flecks of phosphorescent light, if the water be agitated at night.

But there are other creatures which spend their whole lives upon the bottom of the deep sea, and have been dredged from all depths down to four and one-half miles. Here they live in the ice-cold water of the depths, where the darkness is profound and where no current moves. Many of them have very large eyes, or are provided with remarkably long or delicate "feelers," and phosphorescent areas upon their skins, and thus they find their way around in their cold, dark, changeless world. A considerable number of

these deep-sea creatures belong to types which once lived in shallow water along our coasts, but which died out long ago, and are known to us only through their fossils in the rocks.

Marine animals are much more abundant along or near continental coasts than in the open sea far from land, for we must bear in mind that animal life can subsist only upon plant life and that the great food supply furnished by the shallows of a shore are most favorable for the development of a varied fauna.

The great ocean currents, such as the Gulf Stream in the Atlantic, and the Kuroshiwo of the Pacific are the bearers of vast hordes of floating creatures which are thus carried from the tropics far into the temperate regions. Temperature is also a great factor in determining the distribution of marine life. On our own coast, for example, we find that the cold arctic water creeps down the New England coast to Cape Cod, while south of that place the shore water is warmed during the summer by the drift from the Gulf Stream. Accordingly a great number of southern forms extend only as far north as Cape Cod, and similarly many of the arctic creatures can not survive in summer in the warm water south of that cape.

It is even more interesting to see that at Cape Breton, Nova Scotia, we find a number of creatures whose true home is south of Cape Cod, Massachusetts, but which are able to live in the warm water at the mouth of the St. Lawrence, where the Gulf Stream approaches the coast for the last time before its final deflection into the midst of the Atlantic.

So important is temperature in determining the distribution of marine life, that while the creatures of the tropical Atlantic and Pacific on opposite sides of the Globe are, broadly speaking, quite similar, those living north of Cape Cod are almost wholly different from those of the Florida coast.

But the most remarkable condition is seen in the distribution of the creatures of the deep sea, for here the temperature is nearly the same everywhere, being only slightly above the freezing point. Accordingly many of these animals range from Arctic to Antarctic, and from Atlantic to Pacific.

Many forms that live only in deep, cold water, south of Cape Cod come into the shallows on the Maine coast.

In the Arctic regions we find vast numbers of individuals of but few species, whereas in the tropics the individuals are little or no more numerous, but the number of species much greater than in cold regions.

It is a mistake to assume that animals invariably become rarer as we approach the limit of their range; for example, the common scallop is very abundant in Provincetown Harbor, Cape Cod, but is all but unknown north of that place.

An interesting account of the distribution of deep sea animals, and of the floating life, is given by Alexander Agassiz in "Three Cruises of the Blake," 2 vols., 1888, Bulletin of Museum of Comparative Zoology at Harvard College; and a very general discussion of the distribution of animals as a whole is given by Professor A. Heilprin in "The International Scientific Series," Vol. LVII, 1887.

The study of intelligence in lower animals is a subject of fascinating interest. Nevertheless popular writings upon such matters are usually in error, for the authors are too apt to conclude that when the actions of an animal appear "sensible" from our point of view, or evidently serve a useful purpose, they must necessarily be conscious. For example: the caterpillar of the monarch butterfly *(Danais archippus)* feeds only upon milkweed, and is generally found upon the tender young leaves near the top of the plant, where it is surrounded by the juiciest and most nutricious food. Experiments by the author show, however, that we can not conclude that the caterpillar exercises any conscious choice or reason in the matter, for its being there is due to two simple reactions. It has an inborn tendency to crawl upward rather than downward, and it is also strongly inclined to crawl toward the light. If one plant a milkweed in a flower-pot, and then turn it upside-down the caterpillars will soon crawl upward toward the light of the sky, and will thus wander away from the plant and starve to death, although under normal conditions these two reactions would serve to maintain them in the best situation for obtaining food, and prevent their roaming away from the plant.

Nagel and Parker have also shown that if we place a piece of meat upon certain of the tentacles of a sea-anemone, the meat is rapidly thrust into the mouth. If then we place a piece of paper soaked in a weak solution of meat juice it is at first swallowed, but

after a few trials it is invariably rejected. The tentacles on the other side of the animal will, however, conduct the paper to the mouth even after those on the side first experimented upon no longer accept it, and it is evident that the experience of one side of the animal has no effect upon the other side.

It seems reasonable to assume that if an animal can be trained or can learn by experience it has associative memory, and therefore must be conscious, but it is certain that sponges, jellyfishes and worms have no trace of associative memory.

On the other hand Robert Yerkes has shown that the green crab can learn to travel by the shortest path through a labyrinth to its food.

It is also believed that the squids and octopi, which are the highest mollusks, have associative memory.

However, practically all of the instincts of marine invertebrates are inherited, and the behavior of the animal is not altered by personal experience or association with its fellows. They re-act to external stimuli with almost machine-like regularity, and we can generally predict what effect a ray of light, a current of electricity, the attraction of gravity or a change of temperature will have upon the behavior of the animal.

Essentially the same statements may be made concerning the re-actions of our own heart, lungs and digestive organs, and there is no more reason for the assumption that the lower marine animals are conscious, than that these organs of ours are conscious. The instincts of most marine animals are inborn and are inherited from generation to generation, whereas in higher forms some of the instincts are acquired by personal experience, and are not present at birth or necessarily predestined to appear during life.

Interesting studies of this subject are given by C. Lloyd Morgan in "Animal Intelligence," London, 1896; and by Jacques Loeb, in "Comparative Physiology of the Brain and Comparative Psychology," 1902.

It has been proved that each and every animal and plant begins life as a single cell, and that the body of the individual is built up as a result of the division and consequent multiplication of this cell. Indeed, in one great group, the *Protozoa* the entire animal consists of but a single cell, which performs all of the life-

functions. In higher forms, however, the body is composed of an organized system of cells wherein we see a division of labor, some of the cells being digestive, others muscular, others serving to conduct nervous impulses, etc.

In the great majority of marine animals the eggs or young larvæ are cast out into the water, and it is interesting to observe that even such sedentary forms as clams, oysters, starfishes, sea anemones, corals, etc., are nearly all free-swimming in their early life.

It has long been known to naturalists that, in their development, animals pass through stages which recall the adult states of their more simply organized ancestors of the remote past, and when it was discovered that the vast majority of marine larvæ are free-swimming, it seemed probable that the most ancient marine animals were so, and that the sedentary habits of life seen in sponges, corals, mollusks, etc., were of comparatively recent origin. We must not forget, however, that the free-swimming habits of the young are of immense advantage in leading to a wide distribution of animals, and that it may therefore have been maintained through the agency of natural selection at all times, or have been brought about as a result of adaptation.

The stages passed through in the development of all animals are so complex, and yet show such a striking similarity of plan that there can be no doubt of the blood relationship of all forms one to another.

As this is a most interesting and important matter, we will devote some space to its consideration.

We will first speak of a typical case of development, such as is seen in the common starfish, and will then consider the more complex conditions exhibited in the worms, crustaceans and mollusks.

The immature eggs of the starfish resemble a minute sphere, in the centre of which we find a small round body called the nucleus.

When the egg is cast out into the water this nucleus divides into two nuclei, both exactly like the original nucleus. One of these new nuclei is, however, soon detached from the egg as a minute ball, and is thrown out into the water. The nucleus which still remains in the egg then divides into two half-nuclei, and one of

these is constricted off and cast out, leaving the egg with only a half-nucleus.

The egg is then mature and ready to be fertilized. This is accomplished by a single male germ cell, called a *spermatozoon*, myriads of which are cast out into the water by the male starfishes at the same time that the females are setting free their eggs. Each *spermatozoon* is an exceedingly minute cell with a globular front end, and a long lash-like extremity, the movements of which drive it rapidly through the water.

The globular front end of a single *spermatozoon* penetrates the egg and fuses with the half-nucleus; and it is most interesting to observe that this front end of the *spermatozoon* is itself a half-nucleus, in appearance similar to the half-nucleus of the egg. In this manner then is the final nucleus of the egg made up of two half-nuclei, one of which is introduced by the male, while the other is maternal and belongs to the egg itself.

After fertilization a wonderful process sets in. This is called cleavage or cell division. First of all the nucleus divides into two similar nuclei, and these separate while at the same time the egg becomes cut into two, so that each half contains a nucleus. The halves of the egg do not, however, remain far apart but apply themselves closely one to another, so that soon only a shallow furrow marks the position of the cleft which cut them in two. After a few minutes of rest the egg suddenly divides again, each half being cut into two, and this process is repeated again, and again, until we have a great number of little cells all gathered together into a ball hardly larger than the original egg.

Soon, however, we see that the ball is not a solid mass of cells, for the centre becomes hollow and filled with fluid, while the cells range themselves round the central cavity in a single layer. The creature thus becomes a hollow ball, the wall of the ball being composed of a single layer of cells. It is then that we first observe any active movement on the part of the embryo, for the outer surfaces of the cells become covered with minute hair-shaped lashes the rapid movements of which cause it to spin through the water. This little, hollow, ball-like embryo is called a *blastula*. Soon an interesting change takes place, for a part of the wall becomes pressed inward as one might squeeze in the side of a hollow rubber ball. This process is called "invagination,"

The little embryo then has an inside layer of cells as well as an outside layer, and is called a *gastrula*. The cells of the pressed-in part are destined to give rise to the stomach, intestine and digestive glands. On the other hand the outer surface of the embryo gives rise to the skin and nervous system.

All animals from the sponges up to man pass through a *gastrula* stage in which the body consists only of an outer and an inner layer. In many cases, however, as in worms, crustaceans, insects, mollusks, amphibia, reptiles and birds, the egg contains more or less yolk to provide nutriment for the developing embryo, and this introduces modifications of the process of cleavage, and formation of the *gastrula* so that it has taken long and careful study to discover that all embryos are at one time in the *gastrula* stage. Indeed, Huxley discovered that the jellyfishes were practically *gastrulæ* even when adult, for they have only a digestive cavity and an outer skin. In all forms above the jellyfishes, however, we find a system of cells which come to lie between the digestive sac and the outer skin, and which gives rise to the muscles, and in higher forms to the skeleton. Although it will be impossible to do more than to present this crude sketch of the general processes of embryology, one will find a most fascinating field for thought in the study of such admirable works as "The Cell in Development and Inheritance," by Edmund B. Wilson, or the "Text-Book of the Embryology of Invertebrates," by Korschelt and Heider, Macmillan Co.

A most readable and yet condensed discussion of general embryology is given by Richard Hertwig in "Manual of Zoology," 1902, translated by J. S. Kingsley, p. 139–164.

A list of a few of the more general and popular works upon our marine animals may be of aid to those who desire to seriously study the subject

For beginners who are engaged in collecting marine animals, and who desire to learn of their relationships, habits, structure and names, we would suggest:

E. C. and A. Agassiz: Seaside Studies in Natural History, Ticknor and Fields, 1865. 155 pages; 186 illustrations. A clear, popular, account of the structure and habits of our jellyfishes, sea anemones and star fishes and sea-urchins.

C. B. and G. C. Davenport: Introduction to Zoology, Macmil-

lan Company, 1900. 412 pages; 306 illustrations, many of them being photographs from life. Most readable accounts of the relationships of various forms, and also of their habits and anatomy.

A. F. Arnold: The Sea-Beach at Ebb-Tide; Century Company, 1901. 490 pages; 85 plates and numerous figures, most of which are taken from previous publications. A good description of each species, and interesting chapters upon the relationships of each great group of the invertebrates.

A. E. Verrill and S. I. Smith: Report upon the Invertebrate Animals of Vineyard Sound and Adjacent Waters. Report of the U. S. Fish Commission, 1871–'2, 478 pages, 38 plates, 287 figures. Excellent accounts of habits and distribution, together with clear outline drawings of some of the animals.

G. B. Goode, etc.: The Fisheries and Fishery Industries of the United States. U. S. Fish Commission, 1884. Two vols., 895 pages, 277 plates. Valuable to fishermen and collectors.

Good general textbooks upon zoology, embryology and anatomy for those who have had the benefit of an elementary course in zoology:

Richard Hertwig: A Manual of Zoology; Henry Holt & Co. 1902. Translated by J. S. Kingsley. Korschelt and Heider, Textbook of Embryology of Invertebrates, Macmillan Company, 4 volumes, 1895–1900. Arnold Lang: Textbook of Comparative Anatomy, Macmillan, 1891–'96, 2 volumes.

Every student of zoology should read Darwin's "Origin of Species." This work is to the natural sciences what Newton's "Principia" is to the physical and mathematical sciences. But it is more than an epoch making work, throwing a flood of brilliant light upon the dark mysteries of life. Its greatest inspiration to us comes because it is the record of one, who, after years of studious labor, performed under conditions of extreme distress which only love of truth could conquer, came into a realm of thought wherein he saw darkly and imperfectly, what we were, what our race had been, and what our possibilities. His characteristics were simplicity, honesty, and courageous thoroughness; fearlessly following the lead of truth far toward the limit of human understanding.

SPONGES OR PORIFERA

SPONGES are animals. The ordinary bath sponge is only the horny skeleton which in life was encased by living cells. In every living sponge, water is drawn in through numerous small openings, and thrown out through large ones. This water passes through the intricate channels of the sponge which are lined with thousands of minute cells, each provided with a collar, and a thread-like lash, which serves to capture and engulf the minute animals and plants that are drawn in with the water. In some sponges the skeleton is calcareous, and is composed of a vast number of curiously shaped spicules. In others it is mainly horny and fibrous as in commercial sponges, while in some, such as the Venus basket of the China Sea, it is glassy. The eggs develop within the sponge itself and are usually cast out as minute spherical or oblong larvæ covered with cilia which enable the little creatures to swim rapidly through the water. In a few hours or days, however, they settle to the bottom and soon grow into sponges. Sponges of the same species often vary greatly in form, in accordance with the situation in which they grow, and they possess so little individuality that two sponges growing side by side will often fuse into one large mass. Sponges may also be cut into pieces, and each piece will grow into a perfect sponge. Good accounts of our American sponges are given by Hyatt, Memoirs of the Boston Society of Natural History, 1875 and 1877, and Lambe, Transactions of the Royal Society of Canada, 1892–'94, 1896, 1900.

COMMERCIAL SPONGES

Our commercial sponges are found living only in the warmer seas, such as the waters of Florida, the West Indies, the Red Sea and Mediterranean. The sponges from Florida and the West Indies are inferior to those of the old world. There are many varieties of the commercial sponge but they all belong to the genus *Spongia* and have a skeleton made up of tough, closely meshed, horny

fibres. The fleshy parts which cover the skeleton are dark brown or black, and as the living sponge is usually more or less covered with mud or silt it is far from attractive in appearance, or pleasant in odor.

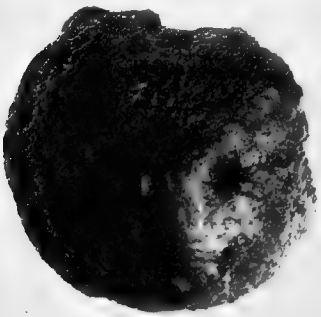

Fig 1; LIVING COMMERCIAL SPONGE (Glove Sponge) The Bahama Islands.

There are always a great number of little pores on the sides of the sponge, and water is drawn through these by means of the constant lashing of vast numbers of cilia which are borne upon the cells lining the passages. This water is forced out through one or more larger openings at the top of the sponge. In this manner the sponge tissues are aerated and the sponge captures the minute organisms upon which it feeds. Commercial sponges do not grow at depths greater than 200 feet, and the vast majority are obtained in water less than thirty feet deep, the best varieties being found at the greatest depth.

The water is so wonderfully clear in the regions where they grow, that the fishermen merely use a bucket having a pane of glass in the bottom through which they look in scanning the bottom for sponges. The sponge is drawn up by a pair of hooks fastened to the end of a wooden pole. It is allowed to die, and is buried in dry sand until it is

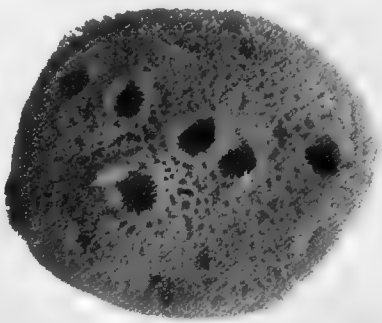

Fig. 2; THE HORNY SKELETON OF THE COMMERCIAL SPONGE (Glove Sponge) from the Bahama Islands.

much decomposed, and then it is washed in the water to remove all of the fleshy parts, leaving only the tough, horny skeleton, which may be bleached in weak hydrochloric acid and hyposulphite of soda.

Sponges grow best on hard bottoms where there is a considerable current to bring food, and to provide them with an abundance of aerated water. In Florida there are five varieties of sponges called "sheepswool," "yellow," "grass," "velvet" and "glove sponges."

Fig. 3; RED SPONGE, Long Island Sound.

The Sheepswool Sponges, *(Spongia equina gossypina,)*, are most valuable, the fishery being worth about $250,000 annually. The fibrous skeleton is very tough and fine meshed, and the interior of the sponge is cavernous while the outer surface is covered with woolly looking tufts of fibres. This is the common large bath sponge.

Fig. 4; RED SPONGE, Long Island Sound.

The Yellow Sponge, *(Spongia agaricina,)*, lacks the woolly tufts characteristic of the sheepswool, and its surface is apt to be fairly even, with numerous pit-like pores. The fishery is worth about $15,000 annually.

The Grass Sponge, *(Spongia graminea,)*, has the shape of a truncated cone the broad end being uppermost. The upper surface contains all of the large openings and is usually depressed, giving the sponge a cup-shape. The sides are furrowed with numerous small openings between the ridges. The fishery is worth about $20,000 annually.

In the Velvet Sponge, *(Spongia equina meandriformis,)*, the surface is apt to show winding channels bordered by flat ridges of fibre. The least valuable is the Glove Sponge *(Spongia officinalis tubulifera, Figs. 1, 2)*, in which the surface is quite even with dense fibres which project outward in fine tufts. The sponge is usually

dome-shaped, not more than eight inches in diameter, and the fibres become brittle with age.

Fig. 5; Clam Shell infested with Boring Sponge, Long Island Sound.

Sponges are reproduced from eggs which develop into free swimming larvæ, but soon settle down upon the bottom and grow into the sponge form. They will also grow very readily from cuttings or spores, and almost any fragment of a sponge is capable under favorable conditions of regenerating a perfect sponge.

A well illustrated paper giving an account of the commercial sponges of Florida is given by Dr. H. M. Smith in Bulletin of the United States Fish Commission, Vol. XVII, 1897, p. 225–240.

Among non-commercial sponges, the Red Sponge, *(Microciona prolifera, Figs. 3, 4)*, is found in shallow water from South Carolina to Cape Cod, and is very abundant upon oyster and scallop shells in Long Island Sound. It can be at once recognized by its brilliant crimson color. When young it forms broad, thin incrustations, but later it gives rise to branches which may be four inches in height.

Fig. 6; THE FINGER SPONGE, Salem Harbor, Massachusetts.

The Boring Sponge, *(Cliona sulphurea, Fig. 5)*, a sulphur-colored sponge, is very destructive to the shells of oysters, clams, etc. It completely honeycombs and dissolves the shell, riddling it with galleries and holes, and finally growing over the outside. It is abundant along the shores from South Carolina to Cape Cod.

The Finger Sponge, *(Chalina oculata, Fig. 6)*, is dull red or yellow in color and grows upon rocks or shells, forming finger-shaped masses about six inches high. At intervals there are large openings on the sides of the sponge which serve to allow the escape of water from the interior. This sponge is common north of Cape Cod at depths greater than fifteen feet.

The Sulphur Sponge, *(Suberites compacta,)*, is a compact, heavy sponge which grows on sandy bottoms off the Long Island coast. When living it is bright yellow, but soon darkens into an ugly brown after death. The surface of the sponge is smooth, rounded and nodular.

The Urn Sponge, *(Grantia ciliata, Fig. 7)*, is common in tide pools on Long Island where it grows in clusters of little urn-shaped sponges, each urn being dull yellow, gray or drab in color, about one-half of an inch high, and with a large opening edged with spicules at the summit. It is found along our coast northward to Greenland, and is abundant on the northern coasts of Europe. Water is constantly being drawn in through sieve-like openings on the sides of the sponge and forced out through the large terminal opening.

Fig. 7; URN SPONGE, Woods Holl, Mass.

JELLYFISHES AND HYDROIDS

A JELLYFISH is an umbrella-shaped creature with tentacles and sense organs arranged at intervals around the outer edge of the umbrella, while the mouth and stomach occupy the position of the umbrella handle. This description applies well to the large jellyfishes called *Scyphomedusæ*, but the smaller kinds called *Hydromedusæ* have a delicate membrane extending inward all around from the umbrella-edge forming a diaphragm which partially closes the opening of the umbrella. Jellyfishes swim by rythmatically opening and closing their umbrella-like bodies.

Fig. 8; PORTUGUESE MAN-OF-WAR.

Jellyfishes are carnivorous, feeding upon small fishes, crustacea, or one another. They capture their prey by means of their tentacles which are armed with thousands of little cells each containing a minute coiled tube so slender that it appears to be a mere thread. When excited these cells burst, and the little threads are shot out with such force that they penetrate the skin of the victim, carrying with them a poison which quickly paralyzes a small fish. The

victim is then held in the stomach of the jellyfish for a few hours or days and the undigested remnant is ejected through the mouth. In common with other low invertebrates, the rate at which jellyfishes grow is dependent upon their supply of food. Indeed one can observe them enlarge after every meal, and when starved they contract in size.

The great majority of the jellyfishes are so small as to escape ordinary observation, but are on the other hand so numerous as often to cause a brilliant phosphorescence of the sea at night.

The eggs of jellyfishes do not usually develop directly into new jellyfishes. In the large jellyfishes *(Scyphomedusæ)* the egg develops into a little pear-shaped creature whose body is covered with vibrating cilia which enable it to swim rapidly. Soon it settles down, and the narrow end adheres to the bottom. Then a mouth and a row of tentacles appear at the upper end. The little creature then grows for some months until suddenly it begins to constrict at intervals, and finally to split up into a series of thin, flat disks, each one of which swims off and grows into a separate jellyfish.

In the smaller jellyfishes *(Hydromedusæ)* the egg changes into a beautiful little tree-shaped animal called a hydroid, and this gives rise to many little jellyfishes which bud out from it in various ways. Some jellyfishes, however, do not give rise to hydroids and many hydroids do not develop jellyfishes.

Descriptions of the jellyfishes of our Atlantic coast will be found in "North American Acalephæ," A. Agassiz, 1865; "Contributions to the Natural History of the United States," Vol. III, 1860, by Louis Agassiz; C. W. Hargitt in "The American Naturalist," 1901, Vol. XXXV; "Das System der Medusen," by Haeckel; 3 vols., 1879–'80, and "Medusæ from The Tortugas, Florida," in the Bulletin of the Museum of Comparative Zoology at Harvard, Vol. XXXVII, 1900 by A. G. Mayer.

The Portuguese Man-of-War, *(Physalia arethusa, Fig. 8).* This beautiful animal is sometimes seen floating along our coast late in summer, but its home is in the tropical Atlantic and the Gulf Stream. The large pear-shaped float is filled with atmospheric air, and beautiful iridescent blues and pinks play over its surface and along its comb-like crest. Attached to the float there is a complex colony of

tentacles, finger-shaped feeding mouths, and grape-like clusters of reproductive organs. The tentacles are arranged in clusters, some being long and others short. When the wind blows, the long tentacles stretch out fully fifty feet, thus forming a drag to prevent a too rapid drifting of the colony. These tentacles are flat and ribbon-like and along one edge we see a purple line of bead-like stinging organs, which serve in the capture of fishes upon which the *Physalia* feeds. They inflict a most painful sting, and almost instantly paralyze small fishes. When a fish comes in contact with the tentacles they immediately adhere to it, and the struggles of the fish cause the tentacles to contract, thus bringing the prey within reach of the numerous mouths which soon fasten upon it. If the fish does not struggle the tentacles soon cease to contract, and thus the mouths may be unable to seize upon their food. Despite its formidable weapons, however, the *Physalia* is greedily devoured by Loggerhead turtles, but the turtle always closes its eyes when it seizes the prey.

When very young the *Physalia* may sink for a time beneath the surface upon discharging the gas from its float; but in later life it loses this ability and remains constantly floating over the ocean at the mercy of the winds and currents. Only male Portuguese men-of-war are known, the female never having been observed.

Velella mutica, is an exquisite creature rarely seen along our coast, but it occurs in great swarms in the tropical Atlantic. The body is an oblong disk about four inches long, and deep blue-green in color. The upper side of the disk is occupied by the chambered, gas-filled float which is chitinous, and gives rise to a sail-like crest. On the under side of the disk we find a large central feeding-mouth surrounded on all sides by numerous little mouths and reproductive polypites. Near the outer edge of the under side of the disk there is a row of long blue tentacles. Large numbers of little jelly-fishes are constantly budding off from the sides of the reproductive polypites and swimming away in the water; but their further development is unknown.

Porpita linnæana, is related to *Velella* but is smaller, being only about one inch in diameter. Also the disk is flat and circular, and there is no sail-like ridge to the float. When seen in the water it appears as a deep blue circle, while the chambered float at the centre glistens with a beautiful greenish iridescence. Underneath we

find feeding polypites, reproductive polypites and tentacles very much as in *Velella.*

Porpita is rare along our coast, but between Cuba and South Carolina it is sometimes so abundant as to fleck the ocean for miles with specks of brilliant blue.

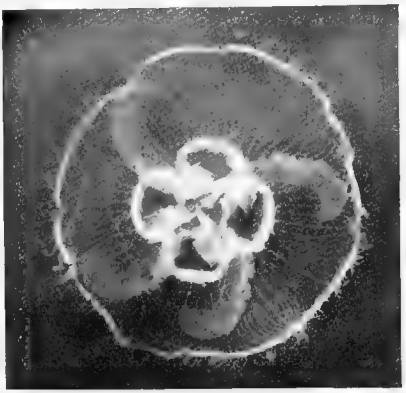

Fig. 9; MILKY-DISK JELLYFISH, Vineyard Sound.

The Sea-Blubber, *(Cyanea arctica)*, is the largest known jellyfish. In the cold waters north of Cape Cod it grows to huge proportions, and one was found by Dr. Alexander Agassiz which measured seven and one-half feet across the disk and whose tentacles were fully one hundred and twenty feet long. On the Long Island coast, however, it grows to a much smaller size and thrives only in spring and early summer, disappearing about the middle of June Large as these creatures are, however, when dried in the sun it is found that the animal substance is only $\frac{5}{100}$ part of the whole; the vast bulk of the creature's body being composed of sea water.

The disk is amber-colored with a rosin-colored centre marking the stomach-space. There are sixteen notches at regular intervals around the edge of the disk, and eight of these notches are occupied by sense organs which contain granular concretions.

On the lower surface of the disk one finds the central mouth surrounded by veil-like lips, and eight clusters of tentacles.

The eggs are caught in the veil-like folds of the lips and set free as little pear-shaped larvæ which swim rapidly through the water by means of their cilia. Soon, however, each larva settles down upon the bottom and develops into a polyp having a terminal mouth surrounded by tentacles. After feeding and growing for some months the polyp begins to display constrictions at regular intervals, and soon it splits up into a series of disks, each one of which is set free and becomes a jellyfish.

The Milky Disk, *(Aurelia flavidula, Fig. 9)*, is common north of Cape Cod to the Arctic Ocean, but is not very abundant along our coast. The disk is about one foot in diameter, is flatter than a hemisphere and is slightly milky in color, while the four horse-shoe-shaped reproductive organs near the centre are yellowish-white or pink. The mouth is at the centre of the concave side of the disk and is surrounded by four long frilled lips. Sixteen straight and sixteen pitchfork-shaped vessels extend outward from the central stomach to the edge of the disk. The little pear-shaped larvæ are cast out in immense numbers, and after swimming about for a few days, they settle upon the bottom and develop a ring of tentacles in a zone around the mouth. Finally the body of the larva splits up into a series of disks, each one of which swims off and develops into a full-grown jellyfish.

Fig. 10; SPECKLED JELLYFISH.

The Speckled Jellyfish, *(Dactylometra quinquecirra, Fig. 10)*, is found in a few localities, as at Tiverton, Rhode Island, in great abundance, during the latter half of the summer, and it occurs in the upper reaches of many other bays and estuaries from Florida to Cape Cod.

The disk becomes about one and one-half feet in diameter, and its margin bears thirty-two notches and, when fully grown,

forty tentacles. The veil-like lips around the mouth form long, graceful curtains often two and one-half feet in length. This medusa can be at once distinguished by its amber-pink coloration, and the sixteen spoke-like areas of reddish specks upon the convex side of the disk. There are eight sense organs, each containing a spherical mass of concretions. These are situated at regular intervals within notches at the disk-margin.

The Milky Cross, *(Staurophora laciniata)*, is abundant along the Atlantic coast north of Cape Cod, during the summer months, and is occasionally seen along our coast in spring. The appearance of a milky-colored cross is produced by the large cruciform mouth bordered with veil-like frills containing the reproductive organs. It is from four to eight inches in diameter. There are numerous little eye spots at the base of the tentacles, upon the bell margin.

The Thimble-Jelly, *(Melicertum campanula)*. This little Arctic jellyfish resembles a large thimble of clear jelly-like substance with eight, yellow, radial canals extending from the stomach at the centre of the concave side of the thimble to the edges forming, so to speak, the spokes of a wheel. The edge of the bell is provided with numerous tentacles. It is exceedingly abundant until midsummer, north of Cape Cod, but is found on our coast only in the spring.

(Gonionemus murbachii, Fig. 11). This interesting little jellyfish is familiar to all who study at the Woods Holl Laboratory, for it is very abundant in the Eel Pond at that place. The bell is transparent, somewhat flatter than a hemisphere, and when full grown it becomes about one inch in diameter.

Fig. 11; Jellyfish, *Gonionemus murbachii*, Woods Holl, Mass.

About eighty long, flexible tentacles arise from the side of the bell near the rim. Each of these bears a sucker-like disk upon its upper side near its extremity, and the extreme tip of the tentacle bends sharply at right angles. The tentacles are covered with wart-like clusters of minute thread-cells each containing a coiled tube which can be turned inside out as we might do with the

finger of a glove. If the tentacles come in contact with a small fish or crustacean these little stinging-threads are instantly discharged, and on account of their minute size they penetrate the skin of the prey carrying with them a poison, believed to be formic acid, which quickly paralyzes the victim. Scattered between the tentacles there are numerous little balancing organs, which may also serve to detect vibrations in the water. These organs consist of minute capsules each containing a hard spherical concretion. The stomach of the medusa is a four-sided tube at the centre of the concavity of the bell.

Fig. 12; PASSION-FLOWER HYDROID (From Life). Annisquam, Mass.

Four canals radiate outward from this stomach and extend 90° apart, to a vessel which encircles the bell margin at the bases of the tentacles. The genital organs are developed upon these radial canals. They are ribbon-like, but each ribbon is longer than the portion of the canal upon which it is developed, and its edge is therefore folded sinuously from side to side.

The stomach, genital organs and tentacles are rich brown in color with green spots, while the other parts of the jellyfish are transparent and gelatinous.

According to Perkins, the jellyfish is very active upon cloudy days, when it swims rapidly upward to the surface, opening and closing its umbrella-like bell with powerful pulsations. Upon

reaching the surface, however, it becomes suddenly quiet and then slowly sinks down with tentacles widely distended. Frequently it clings to seaweed and other objects by means of the suckers upon its tentacles.

This jellyfish lays its eggs during the summer at about one hour after sun-set. The little larvæ are pear-shaped and swim with the blunt end forward. Soon they settle with the blunt end downward and four tentacles soon develop at the narrow end, surrounding the mouth. Other little pear-shaped larvæ often bud out from the sides of the original one, are set free, and after swimming about for a time settle down as did their parents. It is probable that the larva finally changes directly into a little jellyfish. This medusa was first discovered in the Eel Pond at Woods Holl, by Louis Murbach, 1895. Yerkes and Ayer, in "American Journal of Physiology," Vol. IX, 1903, have made a careful study of the reactions of the medusa to light.

The Passion-Flower Hydroid, *(Thamnocnidia spectabilis, Fig. 12)*, often grows upon sunken ropes, or within shaded tide-pools. It consists in a dense cluster of delicate amber-gray stems, each terminating in an enlarged, pink-colored polyp-mouth surrounded by two rows of tentacles. The stems are each about three inches long, and the beautiful flower-like heads give the creature the superficial appearance of a plant; but it is an animal, and the tentacles serve to capture its prey of small crustacea and etc., which it stings to death by its thread-cells.

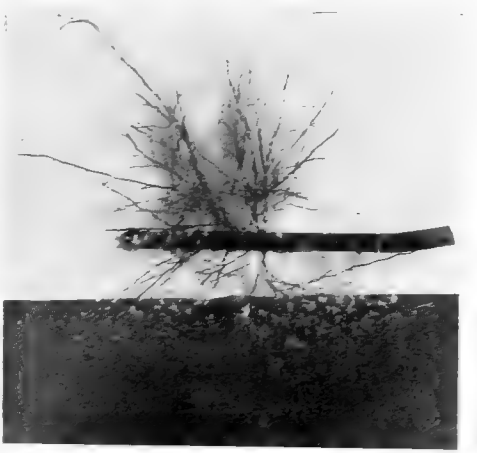

Fig. 13. EEL-GRASS HYDROID, Long Island Sound.

The Eel-Grass Hydroid, *(Pennaria tiarella, Fig. 13)*, grows abundantly upon eel grass or in tide-pools. It is from three to six

inches high, and resembles a little dark-colored tree with branches arranged alternately on either side of the main stem. Each branch gives rise to a series of side branches on its upper side and they each and all terminate in white or pink flower-like heads. These polyp-heads bear the mouths, and each is surrounded by two rows of tentacles which wave through the water intent upon the capture of the small marine animals upon which the *Pennaria* feeds. Jelly-fishes grow out from the sides of the polyp-heads, and within these the eggs develop At times the eggs are cast out before the jelly-fishes are set free, but often the jellyfish escapes from the hydroid and swims about, carrying its eggs with it. The eggs then develop into little pear-shaped larvæ which swim rapidly through the water but soon settle down and change into tree-like hydroids which in turn develop another generation of jellyfishes.

Fig. 14; SEA-PLUME *(Obelia)*, Growing Upon Seaweed *(Fucus)*. From Life.

In spring and early summer large, pale colored, stocks of *Pennaria* are found upon rockweed, piles, etc.; but about the middle of August small, highly colored stocks, with pink heads, are found in great abundance upon eel grass. This was observed by Professor Hargitt in "The American Naturalist," Vol. XXXIV, p. 390.

The Sea Plume, *(Obelia commissuralis, Fig. 14)*, is common upon the wooden posts of wharves or attached to stones or sea-weed. The main stems are fully six inches long, and they give rise to spirally arranged branches which run nearly at right angles to the stem. The creature thus resem-

bles a delicate seaweed or plume, but is in reality an animal. Each branch gives rise to a number of little flower-like polyp-mouths surrounded by tentacles which capture prey.

Jellyfishes develop within capsules at the angles of the stems. These jellyfishes are set free and swim about for a long time, finally growing to be about one-quarter of an inch in diameter. Then they cast out their eggs which develop into plume-like hydroids which in turn give rise to jellyfishes.

The Rainbow Jelly, *(Mnemiopsis leidyi)*, is one of the comb-jellies or *Ctenophoræ*. It is exceedingly abundant along our coast during the summer, but is so transparent that it would escape observation were it not for the brilliant flashes of prismatic red and green that play over its eight rows of comb-like flappers. When full grown the creature is about four inches long, and the outline of the body is pear-shaped with broad wings on the sides. At the narrow end there is a sense organ consisting of a capsule filled with a ball-like mass of concretions. This sense organ enables the creature to maintain its proper position in the water. The central stomach gives rise to a complex system of ramifying tubes which extend through the wings and along under the eight rows of combs. This creature is so delicately formed that it can not be lifted from the water without serious injury, yet it readily captures small fish and crustacea upon which it feeds. At night it gives out a brilliant green phosphorescence when disturbed.

One often finds a long, pink, worm-like parasite imbedded within the gelatinous substance of the Rainbow Jelly. This is not a worm, however, but is a sea anemone, *Edwardsia leidyi*.

SEA ANEMONES AND CORALS

A SEA ANEMONE is a barrel-shaped animal. The bottom of the barrel is fastened to some rock or other firm anchorage, while the upper end bears a slit-like mouth which is encircled by a fringe of tentacles. The mouth leads into a simple tube-like throat, which is bound to the inner sides of the barrel by means of radiating partitions.

The throat-tube is, however, only about one-half as long as the height of the barrel, so that the radial partitions in the lower half

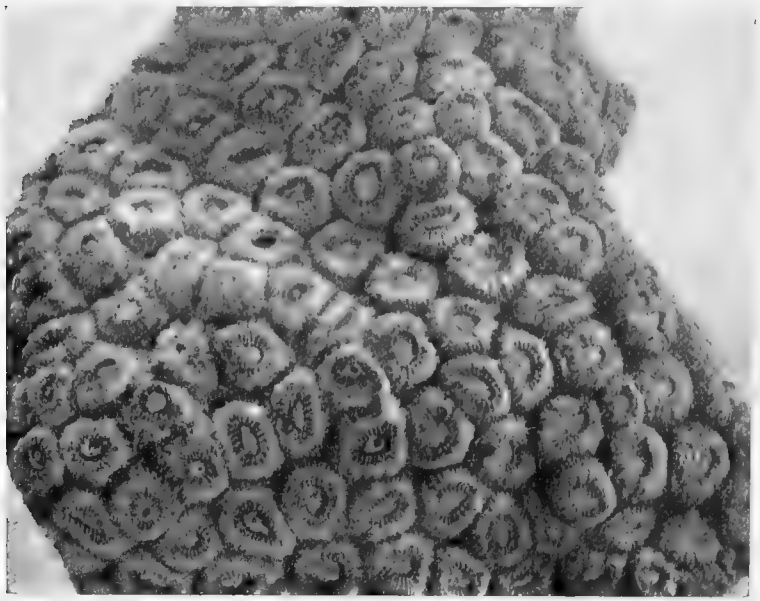

Fig. 15; EYED-CORAL, From Life. Nassau, Bahamas.
Orbicella acropora.

of the barrel cavity do not meet at the centre, but leave an open space which is the "stomach" of the anemone. Sea anemones are among the most attractive of marine animals, beautiful both in

form and color. They vary in size from that of a pin's head to several feet across, and they live at all depths and in a great variety of situations.

A coral polyp is only a sea anemone which deposits a plate of lime salts at the base of its barrel-like body and between the

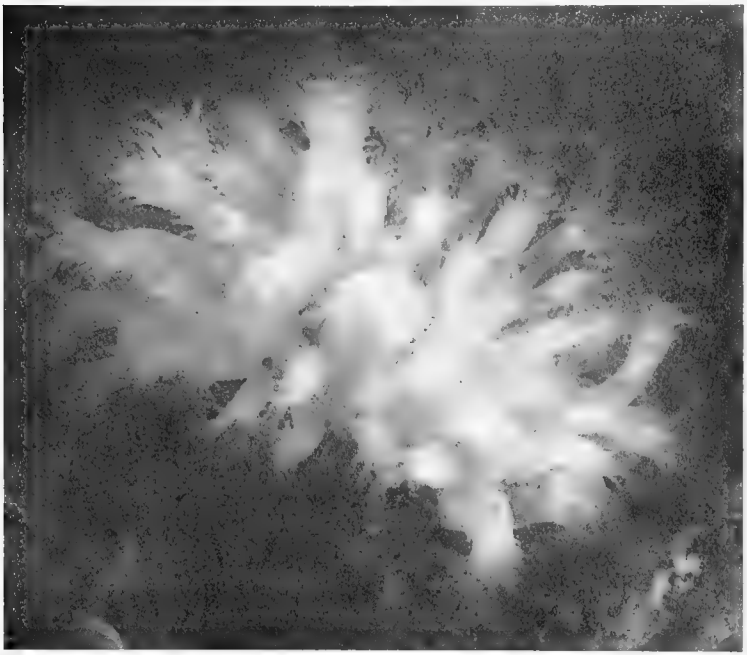

Fig. 16; Star-Coral Showing Living Polyps. From a Specimen in the New York Aquarium.

radial partitions of the stomach cavity. These lime salts form a stony "skeleton" or substance which we commonly call "coral."

It is well to remember that the coral animals are not "insects" but are merely sea anemones which form stony "skeletons."

Although sea anemones and coral polyps resemble beautiful flowers when fully expanded, they quickly contract into a mere dome-shaped mass when disturbed. In this way the coral polyps are protected by withdrawing into their stony cup-shaped bases.

Sea anemones are found in all oceans, but the stony corals are practically confined to tropical and sub-tropical regions and will not usually live in water which is colder than 66° F. In the tropical Atlantic and Pacific thousands of coral islands called atolls have been gradually built up by the constant growth of coral polyps, and every grain of sand on the Bahamas, Bermudas, or Florida Keys was once part of the skeleton of a coral polyp or belonged to some animal or plant which lived among the coral reefs.

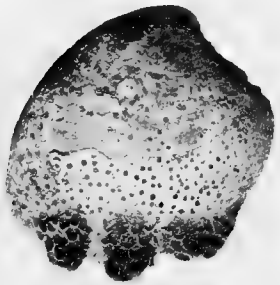

Fig. 17; Stony Skeleton of Star-Coral. Long Island Sound.

The Star-Coral, *(Astrangia danæ, Figs. 16, 17).* This stony coral extends farther into the temperate zone than any other species, being found from the Carolinas to Cape Cod. It is abundant in Long Island Sound where it forms encrusting masses of star-like cups upon stones, dead shells, etc.

The coral polyps are glassy white, and translucent, and have each from eighteen to twenty-four long, tapering tentacles which end in a white knob and are speckled over with white warts. These are the stinging organs which enable the coral to capture its prey of small marine animals. When fully expanded the polyps are about one-eighth of an inch wide and three-eighths high, but when disturbed they suddenly contract so as to become practically invisible. The colony starts with a single polyp but soon others bud out from its base,

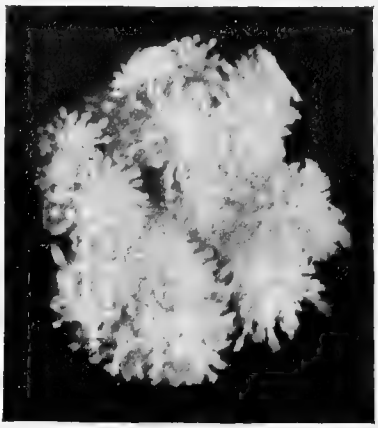

Fig. 18; FLESHY CORAL. Woods Holl, Mass.

and the cluster increases by further budding from the bases of the older polyps until it may be several inches in diameter.

The Fleshy Coral, *(Alcyoneum carneum, Fig. 18)*, is found from the eastern end of Long Island to the Gulf of St. Lawrence. It is

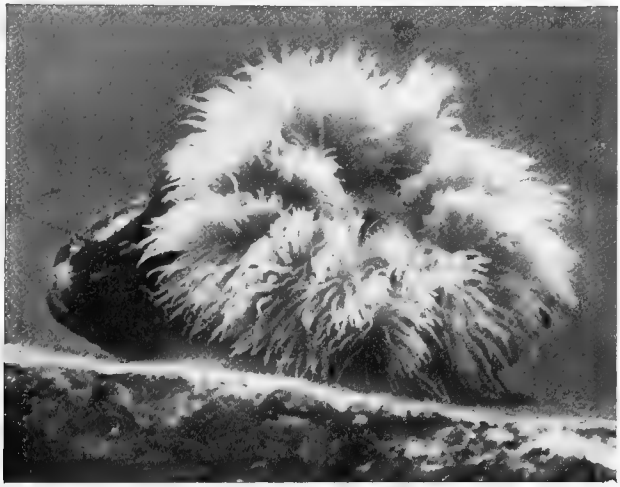

Fig. 19; BROWN SEA-ANEMONE. Expanded. From Life.

rarely seen in shallow water but is common upon rocks at depths greater than 20 feet. When first brought up from the bottom it appears as an ugly, tough gelatinous mass covered with dull yellowish-pink finger-shaped processes. If placed in water, however, the whole mass soon appears studded with beautiful star-shaped polyps, which expand so as to give the appearance of a stump covered with delicate pink flowers.

Each of these polyps has a terminal mouth surrounded by eight tentacles, the sides of which are bordered with rays giving a feathery appearance. The whole colony of polyps develops through constant budding from the sides and bases of the older parts of the colony.

Alcyonaria or fleshy corals are extremely abundant in the tropical Pacific where they often cover the reefs for acres in extent with a tough, leathery-looking carpet studded with eight-rayed

polyps. Others form hemispherical heads bearing beautiful star-like polyps each having eight feathery tentacles, while still others form the sea whips and sea fans so characteristic of an Atlantic reef. In the sea fans, however, the polyps secrete a horny axis which forms the internal framework of the fan and gives a tough support for the fleshy parts which cover its surface. Nothing is more strangely beautiful than these coral reefs where the rich purple sea fans and the chocolate sea whips wave gracefully to the surges in the crystal depths, while brilliant fishes glistening in green, blue, purple and yellow, glide in and out among the shadows of the coral caverns.

The precious coral of the Mediterranean is allied to the sea whips. Its polyps are brilliant white, and have each eight feathered tentacles; while the internal axis of the colony is red and stony.

The Brown Sea Anemone, *(Metridium marginatum, Figs. 19, 20)*, is our common sea anemone, which extends from New Jersey to Labrador. It is abundant in tide pools, and upon the posts and rock work of wharves in Long Island Sound, but it attains a much larger size and more brilliant color north of Cape Cod.

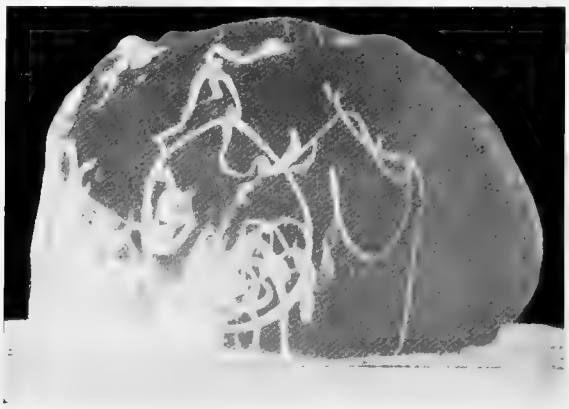

Fig. 20. BROWN SEA-ANEMONE, Contracted. Showing the white thread-like filaments called acontia which are extruded as a means of defense.

Although usually brown in Long Island Sound, individuals of a pure white, delicate salmon-pink, or olive, are common at Newport

and farther north. Large specimens are about three inches wide and four high. When expanded the body is cylindrical with a dense fringe of tapering tentacles surrounding the slit-like mouth. The tentacles are covered with minute hair-shaped organs, or cilia, which wave outward so as to create a current from the base toward the tip of the tentacle, and they are also armed with thread cells that sting the small creatures upon which the anemone feeds.

These sea anemones develop from eggs, but they also slowly divide; an originally single anemone sometimes splitting longitudinally until two are produced. In addition Mrs. M. L. Hammatt discovered that little anemones are often budded out from the base of large ones.

The body of the anemone contains powerful muscles, and when the animal is disturbed these contract so that the tentacles are rolled inward and hidden away, while the body becomes a mere dome-like

Fig. 21; WHITE-ARMED ANEMONE. From Life.
Specimens in the New York Aquarium.

mass. Long, white, thread-like filaments are also extruded through pores in the sides of the body. These filaments *(Fig. 20)*, are called *acontia*, and bear great numbers of stinging thread-cells.

The White-Armed Anemone, *(Sagartia leucolena, Fig. 21)*, is common off the Long Island coast, and extends from the Carolinas to Cape Cod. It is slender, the body being somewhat more than two inches long, while the tentacles are about one inch in length.

It lives in dark situations on the under sides of stones, or upon the shaded piles of wharves below low tide level. Sometimes, however, it is found almost buried in gravel or coarse sand. The body

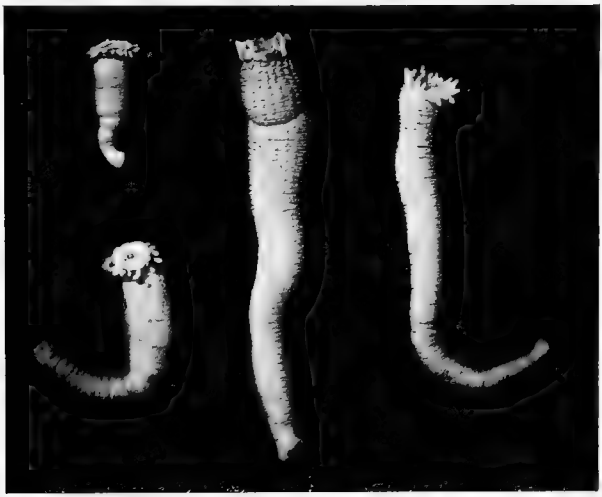

Fig. 22; SAND-ANEMONE, Long Island Sound.

is of a delicate amber-brown, and is semi-translucent while the long tapering tentacles are white or translucent-brown in color. This species thrives well within a salt water aquarium.

The Passion-Flower Anemone, *(Condylactis passiflora)*, is found in the West Indies and Bermudas, where it is abundant upon broken rocky bottoms. It attains a large size, often being more than a foot in diameter and six inches in height. It is a very beautiful anemone. The body is vermillion, while the tentacles are rich turquoise-green with purple tips.

The Sand Anemone, *(Halcampa producta, Fig. 22)*, is common from South Carolina to Cape Cod in sandy or muddy beaches, the elongate worm-like body being buried quite out of sight with only the tentacles exposed.

It is three or four inches long and about one-half of an inch in diameter, but when disturbed it may contract so as to be not more than two inches in length. There are about twenty short, blunt tentacles and twenty longitudinal rows of whitish warts along the

sides of the body. The color is dull yellowish gray, and altogether it is not an attractive object.

The Orange-streaked Anemone, *(Sagartia luciæ)*, is now the most abundant species in rocky tide-pools of Long Island Sound.

It appears to have been introduced upon oyster shells from the south, for previous to 1892 it was unknown along our coast. In that year it was found by Miss L. L. Verrill, near New Haven, and it has gradually spread northward, reaching Salem, Massachusetts, in 1901; beyond which place it appears not to exist.

It is only about one-quarter of an inch wide and three-eighths high, and there are about forty-eight slender tapering tentacles. The body of the anemone is olive green or brown, usually with twelve fine longitudinal orange, or lemon yellow, streaks; while the tentacles are light brown, almost white.

The best description of this anemone is that of Mrs. Gertrude C. Davenport in the "Mark Anniversary Volume," p. 137–144. She discovered that the anemone often splits into two, and the halves soon separate, and grow to their original size. Fragments may also be separated from the base, and then regenerate into new individuals.

The Crimson Anemone, *(Tealia crassicornis)*, is of moderate size, being about two inches high and one and one-half in diameter. It has about 160 blunt tentacles, and the body is covered with tubercles. It is found in tide-pools, and upon rocky bottoms north of Cape Cod, and may be recognized by its rich cherry-red or crimson color, although some specimens are mottled with red and bluish-green. A drawing of this species is given in Agassiz's "Seaside Studies," p. 13, under the name of *Rhodactinia davisii*.

The Parasitic Anemone, *(Edwardsia leidyi)*. Sea anemones live in almost every conceivable situation upon rocky shores, in muddy or sandy beaches, or upon shells which are being carried about by hermit crabs, while others float over the ocean, or swim freely about. Some are even parasitic, and among these *Edwardsia leidyi* is most remarkable. It lives within the transparent Rainbow Jelly *(Mnemiopsis leidyi.* See page 39*)*, and its long, dull pink, threadlike form caused it to be mistaken for a worm.

It is about one and one-half inches long and only about one-sixteenth of an inch in diameter, and there are sixteen blunt

tentacles. Its nearest relatives are slender little sea anemones with eight longitudinal furrows on the body and sixteen tentacles. They live in rocky tide-pools.

The Cake-Anemone, *(Stoichactis helianthus, Fig. 23)*, is common in the West Indies and Bermudas, where it lives in shallow water under rocks or in crevices. It resembles a "pancake" from

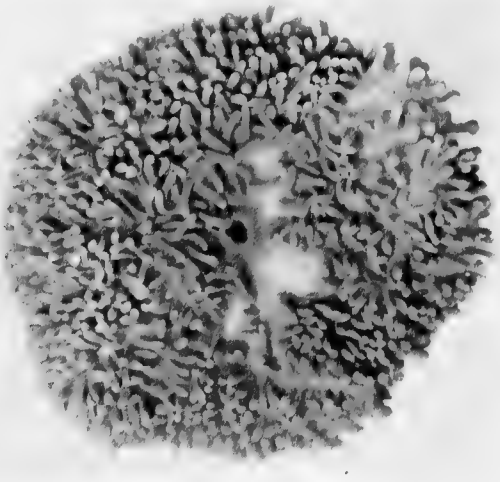

Fig. 23; CAKE-ANEMONE. Tortugas, Florida.

three to five inches in diameter, the oval mouth being in the centre, and numerous short blunt tentacles covering the upper surface. This anemone adheres to rocks by means of its sucker-like base, but it can slowly move from place to place. It is usually olive-yellow, often mottled with green or olive-brown.

STARFISHES
SEA-URCHINS AND SEA-CUCUMBERS

STARFISHES, sea urchins, sea lilies and sea cucumbers are called Echinoderms. In the form of their bodies and arrangement of their organs they usually display five rays, and are therefore known as "radiates." For example, most starfishes have five equally developed arms, 72° apart, recalling the rays of a conventional star. In the Echinoderms the skin usually contains a skeleton composed of calcareous plates of definite shapes, all hinged together in an orderly manner, so as to make a veritable armor which gives rigidity to the body, and protects the soft organs of the interior. In the living starfish one will see hundreds of little tubular feet which arise from the grooves on the lower side of the arms. When the starfish is turned over upon its back these feet stretch out to a remarkable length and wave about, seeking to fasten upon something in order to right the animal. It is then we may see that each of these feet is a hollow tube ending in a cup-shaped sucker.

Similar tube-feet will be seen in five double lines along the sides of the sea urchins. The mouth of the starfish is at the centre of the lower surface. On the upper side, and a little away from the centre between two arms, one will see a spongy-looking area. This is called the madreporic plate, and is the sieve-like entrance to the water-tubes of the starfish which extend down the arms and give rise to little bladder-like vessels one above each tube-foot. The contractions of these little bladders cause the tube-feet to elongate by pressing water out into their cavities.

The upper surfaces of most of the starfishes are covered with spines, but these are much better developed in the sea urchins where, in addition to spines, we find calcareous pincers mounted upon rods, which are used to remove any injurious foreign substance that may fall upon the body of the urchin.

The sea cucumbers, or *Holothuria*, are worm-like in appearance, but are nevertheless closely related to starfishes and sea urchins.

They have no spines and their skeleton is often reduced to minute anchor-shaped spicules within the skin. The mouth is at one end of the worm-shaped body, and is surrounded by feathered or branching tentacles. In some species there are five double rows

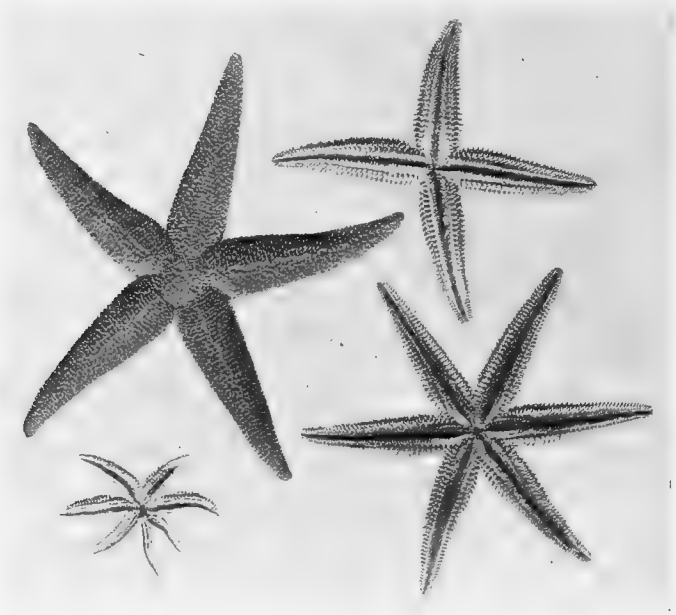

Fig. 24; Variations of the COMMON STARFISH.
From Long Island Sound.

of tube-feet down the sides of the body, but in others these are absent. When disturbed sea cucumbers have the curious habit of casting out their viscera, and afterwards regenerating them. They are sluggish creatures, and either live within the sand or under rocks or crawl slowly over the bottom, feeding upon minute organisms that are contained in the sand or mud which they swallow.

Sea urchins or *Echini* may be compared to starfishes without arms. They are usually provided with a skeleton made for the most part of six-sided plates fused or rigidly joined together. They have five sharp-edged teeth with which they gnaw off minute

seaweeds from the rocks. Some species can even gnaw away the rock itself, and in many parts of the world we find that the sea urchins have literally honey-combed the rocks; indeed we often find a sea urchin living in a cavity whose opening is too small to allow of the animal's escape. The common sea urchin of Europe is sold in the markets during the season when it is full of eggs.

The sea lilies or *Crinoidea* are now among the rarest and most graceful of marine animals. It is probable that all other sorts of Echinoderms are descended from ancestors resembling the sea lilies, for in long past ages they were far more abundant than any other Echinoderms, and even in the age of the chalk they lived in countless numbers in shallow water along our shores, their flower-like bodies mounted upon long delicate stems that formed veritable forests beneath the sea. The sea lily is not a plant, however, but may be compared to a starfish mounted upon a long stem which arises from the middle of its back and anchors it to the bottom of the sea. The mouth is turned upward, and is surrounded by branching arms which sweep gracefully to and fro in search of prey.

The Echinoderms live only in salt water, but they are found at all depths and in all oceans, from the Tropics to the Poles. The vast majority crawl over the bottom, but at least one *holothurian*[*] swims through the water, and was at first mistaken for a jellyfish. Most of them cast their eggs out into the water, and the larvæ develop bands of waving cilia, which enable them to swim about for a considerable time. Suddenly the body of the Echinoderm begins to develop within the larva, and most of the old larval body is absorbed or cast off.

The Common Starfish, *(Figs. 24, 25).* There are two well marked varieties of the common starfish ; one called *Asterias forbesii* extends along the coast from the Gulf of Mexico to Massachusetts Bay but is rare north of Cape Cod. It is found from low tide level to a depth of 120 feet, and may be recognized by its somewhat blunt-tipped arms, tough, spiny skin, and the bright orange madreporic plate.

In the North it is replaced by another form called *Asterias vul-*

[*] *Pelagothuria natatrix*, Memoirs Museum Comparative Zoology at Harvard, Vol. XVII, No. 3, 1894, Plate XIX.

garis which is found from North Carolina to Labrador, but is common only north of Cape Cod. In this starfish the arms are more pointed than in *A. forbesii*, the skin is not so rigid, and the madreporic plate is of the same color as back of the animal, which may be

Fig. 25; Left: HORSESHOE CRAB. *Right:* COMMON STARFISH. *Below:* GREEN SEA-URCHIN.

purple, yellow, brown or beautiful shades of pink or red. It ranges from low tide level to a depth of 1200 feet. Many naturalists consider these two forms to be identical, but the writer found that in *Asterias forbesii* from Long Island Sound, 78 individuals in 10,000 had more or less than five arms, whereas in *A. vulgaris* from Massachusetts Bay only 23 in 10,000 had more or less than five arms. It seems, therefore, that the southern form is more than three times as variable as the northern.

There is a minute red eye-spot at the tip of each arm of the starfish. Hundreds of sucker-like tube-feet arise from a deep groove that extends down the mid ventral side of each arm, and between two of the arms on the upper side of the disk one may see a bright colored area called the madreporic plate. Its situation marks the sieve-like entrance to the water tubes of the starfish.

The mouth is at the centre of the lower side of the disk and is surrounded on all sides by the tube-feet.

In summer and autumn the starfishes are found on rocky places in shallow water, but in winter they live at greater depths.

Starfishes feed upon almost any kind of mollusk, but will also devour barnacles, worms, and occasionally sea urchins or even the young of their own species. It is estimated that in 1888 starfishes destroyed $631,500 worth of oysters on the beds of Connecticut alone. Their mode of feeding is interesting. The starfish folds its arms over the clam or oyster, and hundreds of the sucker-like tube-feet fasten themselves to the valves of the shell, so that finally the mollusk yields to the constant pull of the starfish, and the shell gapes open. Then the starfish turns its stomach inside out and engulfs the mollusk. It has been found by experiment that a large starfish can exert a steady pull of over two and one-half pounds and that this is sufficient in time to open the valves of a clam or mussel.

The eggs of the starfish are discharged into the water in greatest abundance during the last three weeks of June, although they are also to be found throughout the summer, and occasionally even in winter. These eggs soon develop into little transparent larvæ covered with tortuous lines of waving cilia, and provided with long flexible tubercles. They swim slowly about near the surface, and feed upon minute organisms until they grow to be about one-eighth of an inch long. Then the upper and lower halves of the star begin to develop upon both sides of the stomach, and in a few hours all of the anterior part of the larva and the tubercles are absorbed, and only a minute star, about as large as a pin's head, is seen upon the bottom of the ocean.

Myriads of these little stars settle upon sea weeds and eel grass, and begin at once to devour the young clams which also begin life in the same places. Professor Mead found that one of these little stars devoured over 50 young clams in 6 days. The starfishes grow rapidly, and in one year they may have arms $2\frac{1}{2}$ inches long and be ready to spawn.

It is certain that the menhaden devour myriads of starfish larvæ as they swim through the water.

Normal starfishes have five arms, but occasionally one is found

having more or less than this number. Some of these variations are the result of accident, but others are congenital.

Starfishes regenerate readily, and although a single detached arm will not regenerate a new star, it will do so if it be torn off to-

Fig. 26; BLOOD-STAR. Massachusetts Bay, Tide Pools.

gether with about one-fifth of the central disk. Also the central disk if deprived of all of the arms will soon regenerate them. When an arm is injured it is usually cast off voluntarily very near to the central disk, and regeneration begins at this point. Regeneration from the injured tip of an arm is very rare.

By means of their hundreds of sucker feet starfishes are enabled to glide rapidly over the softest mud. They can also climb readily and if turned over will quickly right themselves. When the water is perfectly flat and calm they can even move sucker-side uppermost along the surface of the water.

The Blood Starfish, *(Cribrella sanguinolenta, Fig. 26)*, is smaller than the common starfish, and its arms are rarely more than an inch long. It is pink or reddish and the arms are almost smooth, being covered with numerous little warts. The leathery skin is quite soft and flexible, and the arms are rounded in cross sections, and taper to a point.

The eggs are not cast out into the water, but are held around the mouth of the mother until they have developed into little starfishes. This creature is abundant within rocky tide-pools from the eastern end of Long Island to the Arctic Ocean.

The Mud Starfish, *(Ctenodiscus crispatus, Fig. 27)*, is abundant upon muddy bottoms at depths greater than 100 feet from Cape Cod to the Arctic Ocean. The upper surface is covered with a flexible skin beset with numerous regularly arranged granulations. The sides of the arms are straight and vertical, giving the starfish the appearance of a five-rayed cake cut out of a thick sheet of dough.

At the centre of the upper surface of the disk there is a projecting papilla. In this connection it is interesting to observe that starfishes are probably descended from forms which were attached to the bottom by means of a stalk that extended downward from the middle of the aboral side, and it is possible that the little blunt

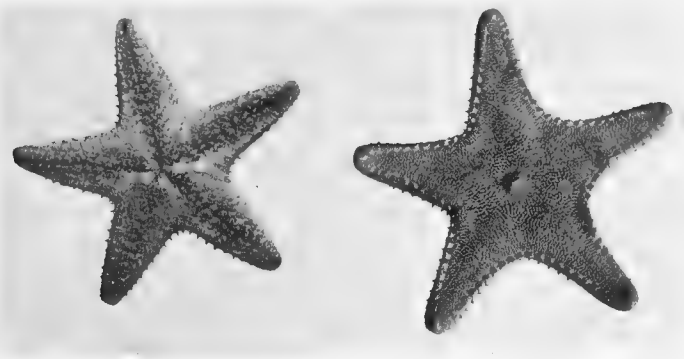

Fig. 27; MUD-STAR. From a Depth of 120 Feet Off Cape Ann, Mass.

papilla seen in the mud star is the remnant of the base of such a stalk that has long since ceased to serve as an organ of attachment.

The feet of this starfish have no terminal suckers, and serve merely to push the animal along as it glides over the mud. The arms are sharp-pointed although short and blunt, and the creature is about two and three-quarters of an inch in diamter.

The starfish is dull ochre-yellow or slightly greenish in hue. It swallows large quantities of mud, and probably subsists upon minute organisms contained therein.

The Giant Starfish, *(Pentaceros reticulatus, Fig. 28)*, is found on sandy bottoms, usually at depths greater than ten feet, off the Florida coast and West Indies. It is the largest of our starfishes,

the disk being about five inches thick, and one and one-half feet in diameter. The five arms are short and blunt, and the upper surface is covered with short, blunt, rounded spines, with a network of ridges between them. The color is brown, or brownish-yellow.

Fig. 28; GIANT STARFISH.
From Sandy Bottom at Tortugas, Florida.

The Green Serpent Starfish, *(Ophiura brevispina)*, is a West Indian and Tropical Atlantic species, but it is common in some parts of Long Island Sound where the bottom is covered with eel grass, as in Great Peconic Bay. It is dark, rich olive green in color, and the central disk is five-sided and about one-half of an inch wide. The long, slender arms arise sharply from each of the five angles of the central disk. These arms are each about two and one-half inches long, and are covered with scales which give rise to short spines along the sides. In life they thrash about in a snake-like manner.

The Serpent Stars are the most active of all starfishes, for their long, flexible arms and tube feet enable them to clamber rapidly over the ground. Although no eyes are known to exist they readily perceive the approach of an enemy, and will dart into the nearest rocky crevice with remarkable rapidity. If one of the arms be seized, it is immediately thrown off leaving the remaining parts of the Star to escape.

The Brittle Starfish, *(Ophiopholis aculeata, Fig. 29)*, is readily distinguished by its mottled coloration in light gray and purplish brown, no two individuals being alike in pattern. The disk is

granulated with minute spines, and the arms are provided with rows of stout, blunt spines, usually six in a row. There are ten egg-pouches on the lower side of the disk near the points of origin of the five arms. The starfish is rare in shallow water but is abundant at a depth of about 100 feet, where it crawls about among the rocky crevices. It extends from the coast of New Jersey to the Arctic Ocean, and is common on the northern coasts of Europe, and the Pacific coast of North America. It is figured by Lyman under the name *Ophiopholis bellis.*

Fig. 29; BRITTLE STARS.
From Life. Tide Pools; Annisquam, Mass.

The Basket Starfish, *(Astrophyton agassizii,)* is a species of serpent star which is interesting in that the arms branch in a forked manner. The central disk is five-sided, and the arms arise from the five angles. At each angle we see two main branches of the arms, then each of these forks giving four branches, and these soon fork again, giving eight. This process is repeated, until, according to Governor John Winthrop of Connecticut, who first described this creature in 1670, the arms give rise to 81920 terminal branches.

The basket star walks upon the tips of these branches, with its body elevated above the ground, and a perfect trellis work of arms sloping outward, so that the creature is about one and one-half feet in diameter. It is dull yellow and brown in color, and is covered

with a tough skin. The basket star feeds upon unlucky fishes which may seek a retreat within the branches of the trellis, only to be seized and devoured. It is found along our North Atlantic coast from the eastern end of Long Island northward, and although rare in shallow water, it is abundant at depths of twenty feet or more, being especially common off Provincetown or in Eastport Harbor.

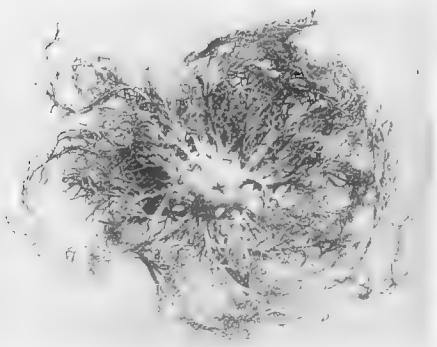

Fig. 30; BASKET STARFISH. Tortugas, Florida.

The Purple Sea Urchin, *(Arbacia punctulata, Fig. 31)*, a dark brown or brownish-purple sea urchin, is quite common on broken rocky bottoms along our coast from Mexico to Cape Cod. The body is globular and hemispherical, and about one and three-quarters inches in diameter. It is protected by a skeleton formed within the skin, and composed for the most part of six-sided calcareous plates arranged in an orderly manner. The body is covered with conical spines of various lengths up to about three-quarters of an inch. These are found chiefly in five broad radii regularly spaced around the body, while between these spiny areas one sees five narrow spaces almost devoid of spines. There are five double rows of tube feet provided with terminal suckers. These arise in the spiny areas and may stretch out so as to become longer than the spines themselves. At the

Fig. 31; PURPLE SEA URCHIN.
Cold Spring Harbor, Long Island Sound.

centre of the under side is the mouth with its five white teeth provided with powerful muscles which enable them to grind the vegetable food upon which the sea urchin lives. The mouth leads into a coiled intestine which opens by a pore at the summit of the body. Around this opening in the areas devoid of spines, are five little pores which are the openings of the reproductive system. In summer the eggs are cast out through these pores, and float in the water where they rapidly develop into little translucent larvæ with reddish spots, and provided with eight long processes which are rendered straight and rigid by calcareous rods. After swimming about, and devouring small creatures for several weeks the sea urchin suddenly develops in the posterior end of the larva, most of the body of which is absorbed and withers away in a few hours, leaving, upon the bottom, a minute globular sea urchin not larger than a pin's head.

The Green Sea Urchin, *(Strongylocentrotus drobachiensis, Fig. 25)*, is found in the deep waters of Long Island Sound but north of Cape Cod it occurs in shallow tide-pools, and on the Maine coast it literally covers the rocks. It extends into the Arctic Ocean, and is found on the north Pacific coast. It may be at once recognized by its resemblance to a greenish chestnut bur. The body is flatter than a hemisphere, about two inches in diameter and densely covered with sharp pointed spines not more than three-eighths of an inch long. In some individuals these spines are tipped with dull violet. In addition to the spines, there are also a large number of little pincers mounted upon rod-like bases. These are used for the removal, or retention, of refuse material which may fall upon the sea urchin. The five double rows of long, slender, tube-feet allow the animal to cling to the rocks over which it slowly glides in search of the algæ, and small organisms upon which it feeds. It often covers itself with bits of seaweed and other fragments.

The Stinging Urchin, *(Diadema setosum)*, is abundant along the Florida coast and in the West Indies, where it is often seen in clusters upon the sandy bottoms. These urchins are velvety black, about four inches in diameter, and are covered with sharp pointed black spines, some of which are fully four inches long. These spines wave rapidly about upon the approach of an enemy, and if the urchin be seized, they penetrate the skin of the attacking person and break off, inflicting a most painful sting.

When young the spines are banded with dark gray and white, but they become dark brown or dark purple in the adult urchin. The body of the urchin is sprinkled over with glistening blue eyes each one of which is provided with a number of prismatic lenses, a retina and nerves.

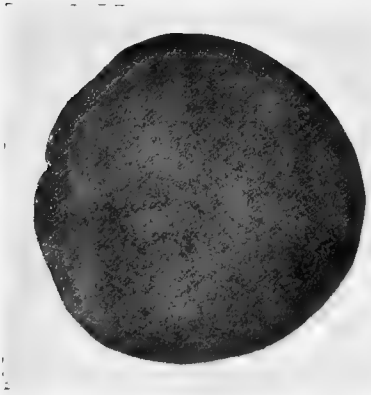

Fig. 32. SAND-DOLLAR.

The Sand Dollar, *(Echinarachnius parma, Fig. 32)*, is found in swarms upon sandy bottoms from New Jersey northward to the Arctic Ocean and the Pacific. It is flat with a rounded edge, about three inches in diameter, and densely covered with short brown spines. The mouth is at the centre of the under side, while the vent is at the margin. Radiating outward from the centre of the upper side one will see the slightly raised pattern of a five-rayed star, the borders of which are outlined by numerous little pores, through which gill-like organs project upward. The sand dollar is enabled to glide over the bottom through the action of its numerous sucker-like feet. When turned over on its back it is unable to right itself, however, and thousands are cast ashore by every great storm. An indelible ink is prepared from sand dollars by pounding them up in water.

The Brittle Sea-Cucumber, *(Synapta inhærens, Fig. 33)*, lives in sand tubes within sandy or muddy beaches from the Carolinas to Cape Cod, and is also found on the coasts of Europe. At first sight it resembles a worm, but it is an Echinoderm closely related to the starfishes and sea urchins. Its body is highly contractile, but when extended is about one-eighth of an inch in diameter and more than a foot long The creature is translucent with five white lines marking the places where muscle bands extend down the body. The skin is covered with little white dots that indicate the places occupied by minute calcareous anchors which enable the animal to obtain a hold when moving. The mouth is at the front end of the long worm-like body and is surrounded by twelve feathered tentacles. The coiled

intestine extends the entire length of the body, and may be seen through the translucent skin, especially when it is distended by the sand which the creature constantly swallows in order to obtain the minute organisms upon which it feeds.

The *Synapta* lives within a tube made of fine sand particles aglutinated with adhesive slime. This tube is made up of a series of rings. The *Synapta* selects little particles of sand with its tentacles, and then fastens them together so as to form a ring around the mouth. The ring is then forced down the sides of the body by muscular contraction, and thus a tube is finally made within which the creature lives.

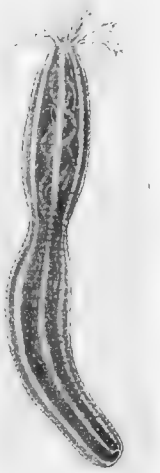

Fig. 33. BRITTLE SEA CUCUMBER

Our *Synapta* has the curious habit of breaking itself into pieces by muscular constriction, and if placed in unfavorable conditions, it soon breaks up into numerous short lengths.

A good figure of it is given in Agassiz's "Seaside Studies," under the name of *Synapta tenuis.*

The Red Sea-Cucumber, *(Synapta roseola)*, closely resembles *Synapta inhærens* but can be at once distinguished by its reddish color, and by the fact that it lives under stones or in gravelly beaches, never in sand or mud.

The Crimson Sea-Cucumber, *(Cuvieria squamata)*, is found along the New England coast north of Cape Cod. It is of a brilliant red color, and the sides and back are shingled with round-edged scales. The lower side of the body is free of scales, but is provided with three rows of tube-feet bearing suckers.

There are ten tentacles which branch profusely and resemble beautiful red trees almost as long as the body. The creature becomes about eight inches long. The brilliant red larvæ, about as large as a pin's head, occur in myriads in the ocean during the spring and early summer months.

THE WORMS

THE worms include a large number of creatures which differ greatly one from another, both in form and in habits of life. They are found in almost every imaginable situation, although generally dependent upon moisture for their development. Many sorts of worms are parasites, and no animal is wholly free from their attacks.

Although repulsive at first sight, worms are really among the most interesting of all animals, for a careful study of their development and structure shows that crustaceans, insects and mollusks are probably descended from worm-like ancestors.

The flatworms or Platodes are among the simplest of all worms. The free-swimming flatworms are common upon seaweed-covered rocks, or upon dead shells. They are generally small creatures more or less leaf-shaped with the front end of the body bluntly rounded. They crawl or swim with a wave-like motion. The sucker-like mouth is upon the lower surface, never at the extreme front of the creature; and the intestine ends blindly, so that undigested particles of food are cast out through the mouth. Numerous little eye-spots and sensory hairs are often seen on the upper surface of the worm, and the nervous system is well developed. The brain is near the front end, and gives rise to two main nerve branches which extend down the body near the lower surface and are joined at regular intervals by cross fibres, making a ladder-like arrangement. The flatworms often lay their eggs in cocoons or capsules, each capsule containing a considerable number of eggs, only a few of which develop; the remainder being devoured by the successful larvæ.

The tapeworms and flukes are related to the flatworms, and are parasitic within many animals. The development of these parasites is interesting, for example the tapeworm produces eggs which develop into little embryos, each with four or six hooks and suckers, and which are then cast out and die, unless accidentally swallowed by some other animal. In this event, however, the little tapeworm gets rid of its egg-shell, and bores its way through the wall

of the stomach of the animal, and lives somewhere within its body. The worm, however, does not usually grow to any great size or develop any segments, but remains little more than a "head" with hooks and suckers. If, however, the animal within which it is living be devoured by another, the little head is set free and attaches itself to the walls of the stomach of the new host, and then it grows to an enormous length, forming hundreds of segments which develop thousands of eggs, and are finally cast out one after another through the alimentary canal of the host.

The highest of the worms are called Annelids, for their bodies are ringed or divided by constrictions into a number of segments. The head segment contains the mouth and is often provided with feelers and eyes. Then follow a large number of body segments quite similar each to each. These often bear flapper-like side appendages which are both gills and feet. The posterior segment usually has one or more pairs of feelers. The intestine runs straight through the body from one end to the other, and the throat which is often armed with teeth, can be turned inside out. There is a well developed brain in the head segment and a chain of nerve fibres extends down the lower side of the body, with a knot-like mass of nerve cells in each segment. The eggs of many Annelids are cast out into the water where they divide into a number of cells, and soon develop into little free-swimming larvæ which are apt to be tack-shaped, the body being elongated, and the head broad and flat. There is a ring of waving cilia around the edge of the broad head of the larva, and another at its posterior end. The mouth is at the narrow edge of the head of the tack, and the intestine bends at right angles and runs entirely through the body, opening at the posterior end. There is usually a sense organ or brain at the centre of the head of the tack, and often we find sensory bristles or hairs at this place. Larvæ of this sort are so common that a special name, *trochophora*, is given to them. Soon the flapper-like legs develop along the sides, and the body becomes segmented and gradually changes into the form of the adult worm. But in addition to this development from eggs many worms increase in even more interesting ways. For example, in some forms called *Syllidæ*, we often find that eyes and feelers begin to develop at regular intervals upon certain segments of the body of the worm, and then

the original worm breaks up into a number of individuals each provided with eyes and feelers.

In the Palolo worms *(Eunice)* of the tropical Atlantic and Pacific oceans, the eggs are contained only in the posterior end of the worm; and this end is cast off early in the morning of the day of the last quarter of the moon, at the Tortugas, Florida, in July; and in the Pacific in November. This cast off end then swims upon the surface for about an hour, and finally contracts so as to squeeze out all of the eggs after which it sinks to the bottom and dies, leaving the eggs to develop, and the forward end of the worm to regenerate a new posterior part.

The Ribbon-Worm, *(Meckelia ingens, Fig. 34)*, is common in muddy or sandy beaches from South Carolina to Cape Cod where it lives buried beneath the ground near low water line. When fully stretched large individuals are about ten feet long, but when contracted even the largest are not more than five feet in length. Commonly the worms are not more than three feet long and about three-quarters of an inch wide, being flat and ribbon-like with bluntly pointed ends, and of yellowish-white color. The body is slimy and the skin is covered with minute cilia which wave constantly. These however can be detected only with the microscope.

This worm is remarkably active and is an excellent burrower, forcing its way through the sand with considerable rapidity. It is also a good swimmer, throwing its ribbon-like body into sinuous waving lines as it moves through the water. When disturbed it rapidly shoots out a long tubular proboscis which arises from a pit on the dorsal side of the head and is not a part of the throat. This proboscis is sometimes thrown out so violently that it breaks off, and then wriggles about very much as if it were a complete worm, while another proboscis is soon regenerated. The proboscis is covered with an adhesive slime, and serves in the capture of prey; for this worm feeds upon other worms which it devours entire. The mouth is on the lower side of the head.

The development of the ribbon-worms or Nemerteans is interesting. The larva is helmet-shaped with a broad head region, and covered with cilia which enable it to swim rapidly. After a time parts of the outer skin sink down in four pit-like depressions into the body of the larva and these grow together around the intestine,

and thus the little worm develops, as it were, within its own larva, which shrivels and is cast off.

The Pink Ribbon-Worm, *(Meckelia rosea)*, is smaller than *M. ingens*, never being more than about ten inches long and one-quarter of an inch wide. It has a thread-like proboscis which can be

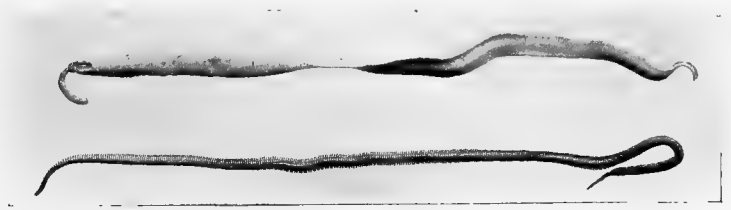

Fig. 34; Upper. RIBBON-WORM.
Lower. OPAL-WORM.

shot out with remarkable rapidity, and is fully ten inches long. This worm is dull red or flesh colored, and lives in sand near low water mark. The sand adheres tenaciously to the slime-covered body of the worm.

The Sea Mouse, *(Aphrodite aculeata, Fig. 35)*. This remarkable worm is oval in shape, and about three inches long and one and one-half wide. The skin is dull brown but the sides are covered with numerous hair-like bristles, many of which glisten with brilliant green, red and yellow iridescence. The head bears a pair of tapering feelers, and there are about forty pairs of legs provided with short, stiff, brown-colored bristles, which extend outward at the edges of the flat lower surface. This worm lives in mud below tide level, and is found from Long Island northward, and is abundant on the northern coasts of Europe.

Fig. 35; SEA-MOUSE.

The Clam Worms, *(Nereis, Fig. 36)*, are very common in muddy beaches where they live between tide levels in burrows lined with mucous. They are segmented, or ringed, each ring of the body bearing a pair of flapper-like gill-feet. The head segment, however, is more complex, for it bears ten feelers, two fleshy "palps," and

four black eyes. When disturbed the worm turns its throat inside out displaying a pair of sharp, horny jaws. The posterior segment of the body has no gill-feet but bears two long feelers.

There are three species of clam worms to be found on our coast. The largest of these is *Nereis virens* which is even more abundant northward and extends to the northern coasts of Europe. It becomes

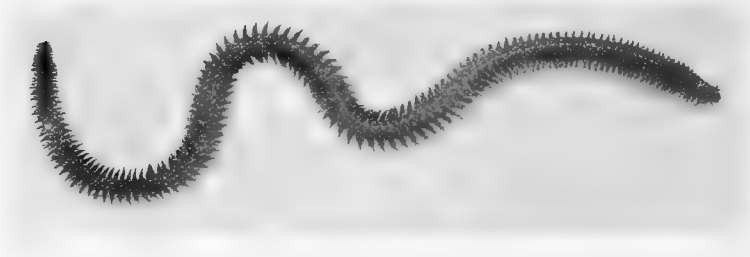

Fig. 36; CLAM WORM. From Life. Long Island Sound.

about one and one-half feet in length, and the body is olive brown or olive blue with a beautiful pearly iridescence. The gills, which are attached to the upper sides of the feet, are leaf-shaped, and are green on the front and salmon red on the middle and hinder parts of the body. The teeth are black.

Nereis limbata is also common. It may be recognized by its horny, yellow colored teeth and small size, being not more than six inches long.

Nereis pelagica is more abundant on the coast of New England north of Cape Cod. The body is widest in the middle, while in the other species of Nereis it is widest very near the head end. On calm nights, during the summer months, these worms leave their burrows, swim about near the surface, and cast their eggs out into the water, where they develop into little pear-shaped larvæ which swim rapidly through the water by means of waving cilia. The development has been thoroughly studied by E. B. Wilson in "The American Journal of Morphology," 1892, Vol. VI.

Nereis is a carnivorous worm and greedily devours other worms, and various marine animals. It is, however, a favorite food with fishes and makes an excellent bait. It is also preyed upon by the ribbon worm.

The Opal-Worm, *(Lumbriconereis opalina, Fig. 34)*, is abundant in muddy beaches from New Jersey northward. The body is ringed, and each ring bears a pair of bristled feet. It is about

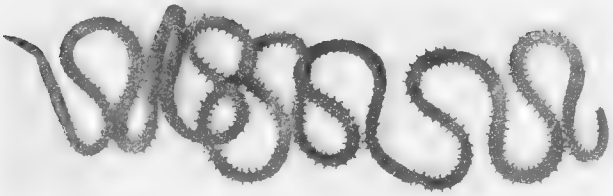

Fig. 37; RED THREAD WORM. Long Island Sound.

eighteen inches long and one-eighth of an inch wide in the middle, the ends gradually tapering. The head is simple and pointed, without feelers. The worm is of a rich bronze color with a brilliant play of opalescent colors over its surface.

The Red Thread, *(Lumbriconereis tenuis, Fig. 37)*. A shovel

Fig. 38; FOUR-JAWED WORM. From Life. Long Island Sound.

thrust into almost any of our muddy beaches will show that the mud is infested with slender, thread-like worms of deep dull-red

color, and about one foot in length. They are so fragile that it is extremely difficult to dig them out unbroken.

The Four-Jawed Worm, *(Euglycera americana, Fig. 38)*, is a stout, active worm about one foot in length and one-quarter of an

Fig. 39; FRINGED WORM. Long Island Sound.

inch wide. The side appendages are small, and function more as gills than as feet. The worm resembles a reddish, iridescent earthworm with a thick body, sharply pointed at both ends. When disturbed it everts its throat, shooting out a balloon-shaped proboscis which is armed with black teeth situated at the four corners of a square. It is a remarkably active worm, and is provided with powerful muscles so that it burrows through the sand very rapidly, and is common in our beaches between tide limits.

The Fringed Worm, *(Cirratulus grandis, Fig. 39)*, is common in burrows in sandy or gravelly beaches at low water mark. The body is dull brownish-yellow, tapering to a point at both ends, but a large number of long, red or orange colored threads arise from the sides, being especially numerous near the head. These are the gills and, when expanded, they are often as long as the body itself, and are thrust out into the water above the worm, which lies safely hidden within its tube-like burrow. When the gills are broken off they squirm about and remain alive for several days.

Fig. 40. TUFTED WORM.

The Tufted Worm, *(Amphitrite ornata, Fig. 40)*, is found in muddy beaches near low tide level, where it constructs a U-shaped tube of mud particles aglutinated together with mucous. The mud around the opening of the tube is heaped up into a crater-like

rim with the opening in the centre. The body of the worm is dull flesh colored with two rows of bristles on the sides of each segment. It is not more than eight inches long and one-half an inch wide near the head, but it tapers gradually from this point, the posterior end being still quite blunt. The head end is provided with three pairs of blood-red, tree-like gills, and a large number of pale flesh-colored tentacles which are constantly expanding and contracting, and by means of which the worm captures the minute creatures upon which it feeds. These tentacles are also used to gather particles of sand or mud with which to construct the tube. The body of the worm remains within the tube with the head near the open end, while the tentacles spread out over the ground in all directions. It is abundant from Cape Cod to New Jersey.

The Blood-Spot, *(Polycirrus eximius, Fig. 41)*, is not more than four inches long, and lives in our sandy beaches immediately below low water mark. The forward half of the body is blood-red and thick, while the hinder part is dull flesh-colored and slender. Each segment of the forward half of the body is provided with a pair of branched gills, while the surface of the hinder part is smooth and has no gills. The most marked characteristic of this worm, however, is the great cluster of blood-red tentacles surrounding the mouth. These are constantly expanding and contracting as the blood flows through them.

Fig. 41; BLOOD-SPOT WORM.

The Shell Worm, *(Serpula dianthus, Fig. 42)*, is common along our coast. It secretes a crooked, stony, white tube upon the sur-

face of rocks, dead shells, etc. Often a number of these calcareous worm-tubes are seen clustered together, as in our illustration. When undisturbed the worm protrudes its beautiful feathered gills, which resemble a little passion-flower projecting from the mouth of the tube. These gills are variously colored in different individuals, some being purplish-brown banded with white and yellow, while others are yellowish-green, orange or lemon-yellow. At the least disturbance such as a shock, or a shadow, the gills are instantly withdrawn into the stony tube, and the opening stopped by a horny disk called the "operculum." These worms are rarely more than three inches long, and one-eighth of an inch wide. The body tapers gradually to the posterior end. In place of the gill-feet of the active worms, we find only a row of little bristles down each side, for these worms are unable to leave their tubes, and the legs which their remote ancestors possessed have degenerated. There are no jaws, but the worm feeds upon minute organisms which are washed into its mouth by the movements of its feathery gills.

Fig. 42; Dead Scallop Shell covered with tubes of the Shell Worm. Long Island Sound.

The Sea Flower, *(Spirobranchus tricornis)*, is a beautiful animal, related to our shell-worm, but is larger and secretes its tube upon the surface of large coral heads, so that the tube becomes covered by the coral, leaving the opening still at the surface. This opening is protected by a sharp spine, and is closed by the operculum of the worm when it withdraws its gills. When expanded these gills resemble a beautiful pink or purple passion-flower, about three-quarters of an inch wide. If a shadow passes over the "flower," however, the gills are instantly withdrawn into the tube. The worm is abundant off the Florida coast, West Indies and Bahamas.

The Acorn Worm, *(Balanoglossus kowalevskii)*. This remarkable worm-shaped creature is found in shallow water, below low tide level, from Massachusetts Bay to the Carolinas. It lives

within sandy beaches in tubular burrows lined with mucous, and the situation of the burrow is always marked by a heap of coiled string-like masses of sand cast out at its mouth. The creature is about five inches long and so delicate that its own weight is sufficient to break it into pieces, so that it must be dug and washed out of the sand with great care. The front end of the body is, however, quite tough and muscular, and is elongate and acorn-like in shape; although it is often expanded and contracted in life. Back of this acorn there is a thickened, collar-like region, and then comes the long, tapering, worm-shaped body. The acorn is usually yellow or dull orange, the collar darker orange, and the body greenish-brown or brownish-purple, often mottled with dull white spots. The mouth is at the lower front edge of the collar, and the creature feeds upon the minute organisms contained in the large quantities of sand which it swallows. The intestine extends straight through the body. The sides of the intestine in the forward part of the body are pierced, however, by numerous gill clefts which open to the outside in a series of pores along both sides of the middle of the back. Now, gill slits are peculiar to the vertebrates, being found either in embryonic or adult life in every known vertebrate from the lowest fishes up to man. Indeed, many naturalists have supposed that *Balanoglossus* might be a survivor of the ancient race which long ago gave rise to the vertebrates. On the other hand the larva of *Balanoglossus* is free-swimming, and bears such a remarkable resemblance to that of a starfish, or Echinoderm, that no one suspected it to be anything else until it was reared and observed to change into a *Balanoglossus*. It is possible, therefore, that *Balanoglossus* is descended remotely from ancient forms which gave rise to both the annelid worms and the Echinoderms. The discussion of this interesting subject would, however, take us too far afield, and the reader is referred to the table of references for further accounts of this species.

THE BRACHIOPODS

IN long past ages these creatures were far more abundant than mollusks, and their shells are among the commonest fossils of the oldest rocks. Now, however, they are nearly all extinct, and are usually found only at considerable depths, or along tropical shores. At first sight one would mistake these animals for clams or mussels, but they are more closely related to worms than to mollusks. In Brachiopods the two halves of each shell on either side of a middle line are similar, whereas in clams and mussels the two halves of each shell are not alike in shape.

A still greater difference, which has been discovered through careful study, is that the shells of the Brachiopods grow on the back and lower side of the animal and the head faces the gape of the shell, whereas in the mollusks the shells grow on the right and left sides, and the ventral side of the body faces the gape of the shell. The mouth in the Brachiopods is flanked by two curiously coiled and feathered arms which lie within the cavity between the shells, and are supported by skeletal rods attached to the upper shell. These serve as gills and also to capture the minute creatures upon which the Brachiopod feeds. In Brachiopods the posterior end of the body is sometimes stalk-like and projects backward either through

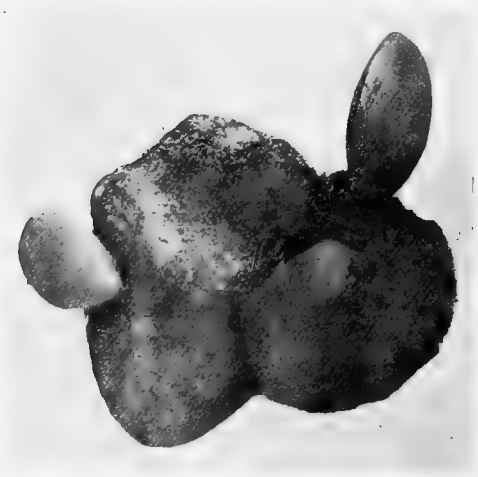

Fig 43. Parchment Shells growing upon a stone. From a depth of 160 feet off Gloucester Harbor, Mass.

an opening near the back of the lower shell, or between the shells.

In some forms this stalk is very small and serves merely to attach the creatures to rocks, etc., while in others it is used in burrowing through sandy beaches. The intestine curves around and opens, if at all, on the right side near the mouth. There is a well developed liver and one or two pairs of tubular kidneys, while the heart lies above the stomach.

The Parchment Shell, *(Terebratulina septentrionalis, Fig. 43)*, is a Brachiopod, and is extremely abundant off the New England coast, on rocky bottoms at depths between 100 and 500 feet, and it is also found off the northern coasts of Europe. At first sight it resembles a little bivalve with elongate, slightly heart-shaped shells, of yellowish color, resembling old parchment The shells are marked with faint radiating ridges, and the lower shell projects backward beyond the apex of the upper. The Brachiopod is attached to rocks, etc., by means of a stalk-like body which projects backward through an opening near the narrow apex of the lower shell. In life the shells move quite freely over each other and often gape open, displaying the beautiful feathered "arms" or gills which lie coiled within the cavity of the shells. This little creature is not more than an inch long and three-quarters of an inch wide. The eggs are laid in the water, and develop into minute free-swimming larvæ covered with moving cilia, and having a tuft of bristles at the head end. The body is pear-shaped, with two constrictions. Soon the creature cements itself to the bottom by the posterior end of the body, and two folds which are to secrete the shells, one on the back and the other on the lower side, grow upward and enclose the body.

THE MOSS ANIMALS AND CORALLINES

Polyzoa or Bryozoa.

A MOMENT'S glance at a bit of seaweed or the most casual inspection of the rocks below low tide level, will reveal the fact they are often covered with delicate lace-like growths, or with more or less highly colored incrustations, or small tree-like forms.

These are the moss animals or corallines. They live in colonies, and grow by budding, the entire colony having grown from a single individual, and thus while the individual creatures are themselves of microscopic size, the colony being composed of hundreds or thousands may spread over a considerable area or constitute a small tree-like, or moss-like, growth.

Each little animal of the colony occupies a separate stony or horny capsule into which it may withdraw and even close the opening with a lid, the aperture being still further protected by spines around its edge.

The mouth is surrounded by tentacles that in many species arise from a horseshoe-shaped or disk-like base. These tentacles are always beset with hair-like bristles which by their movements serve to set up currents, and thus to drive minute organisms into the mouth.

The intestine is U-shaped and bends back so as to open on the dorsal side near the mouth, while the principal nerve centre is situated between the mouth and the vent. In some of the forms there is a single pair of kidney organs, the ducts of which open near the mouth.

We see, therefore, that although these creatures often bear a close superficial resemblance to hydroids they can at once be distinguished by their bristled tentacles and complete alimentary tract. Indeed a careful study of their development and anatomy has shown that they are closely related to the brachiopods and worms, and that their present forms have been brought about by ages of sedentary life. Being stationary they have had little need for sense organs,

and accordingly these have degenerated, and even the internal organs have become simplified. On the other hand, reproduction by budding, and the development of a hard external skeleton have been fostered and are now almost but not quite universal among these creatures.

The eggs are often produced in large oval or flask-shaped cells scattered at intervals over the colony. The little larvæ are free-swimming, being provided with lines of waving cilia. After a time, however, they settle down, fasten themselves to some suitable anchorage, and then begin to increase by budding.

The Moss-Animal, *(Bugula turrita, Fig. 44)*, is very abundant upon piles of wharves and on rocks between Cape Hatteras and Casco Bay, Maine. It grows between low water mark and a depth of 100 feet, and is so abundant that the rocks below low tide level appear covered with its mossy-looking tufts, which are often ten inches long and branch profusely. The older branches near the base of the stem break off, however, leaving a dense tuft of branches near the summit. The main stems are orange-yellow while the terminal branches are yellowish-white. Both stems and branches are, however, usually over-run with minute plant growths and so covered with bits of silt as to be dull brown in color. Examination with a magnifying lens will reveal the little individual animals of the colony, each in its own special sheath. The sheaths being arranged alternately, or on opposite sides of the stem. The bristle-covered tentacles will be seen engaged in the capture of minute organisms; while at intervals one will see curious bird's head shaped appendages, their mouths constantly opening and shutting.

Fig. 44; MOSS-ANIMAL.
Long Island Sound

The Lace Coralline, *(Membranipora pilosa)*, forms delicate, white, lace-like incrustations over seaweeds, dead shells, etc., being especially common upon kelp. It is very abundant from Long Island Sound to the Arctic Ocean; being also found on the northern coasts of Europe.

The Red Crust, *(Escharella variabilis)*, forms a dull-red or pinkish incrustation over rocks and dead shells, layer after layer being formed until the rock becomes thickly coated with a mass bearing a superficial resemblance to coral.

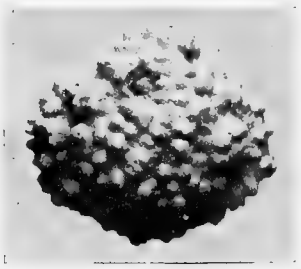

Fig. 45; FALSE CORAL. A coralline animal. Long Island Sound.

It is common from South Carolina to Massachusetts Bay from low tide level to a depth of 150 feet, and is especially abundant in shaded tide pools.

The False Coral, *(Discosoma nidita, Fig. 45)*, forms rough, nodular masses of dull greenish-yellow color, and is extremely abundant in Long Island Sound where it is commonly but erroneously called "coral." These nodular masses are a gradual growth, and are due to layer after layer of the incrusting Polyzoa which always forms over a dead shell or some loose stone. It is found only below low tide mark, and is most abundant in water about thirty feet deep.

THE CRUSTACEANS

THESE are the crabs, lobsters, sand-fleas, barnacles and a host of minute creatures of both salt and fresh water. They breathe by means of plume-like gills which are usually attached to the bases of the legs, and thus the vast majority of crustaceans live in water, whereas insects which breathe through internal tubes called *tracheæ* live on land. A further difference between crustaceans and insects is that in the former the legs are bifurcated while in insects they are simple and linear.

In crustaceans and insects the body is made up of distinct segments separated by constrictions. This is also true of the higher worms but while the legs of crustaceans and insects are jointed, those of worms are usually mere stump-like flappers. Moreover, in worms the body is made up of segments which are similar each to each, whereas in crustaceans and insects the body is composed of dissimilar segments.

In insects we find three distinct regions called the head, thorax and abdomen, and these are marked off one from another by sharp constrictions. In crustaceans, however, we find that there is no sharp line of demarkation between the head and thorax, and only the abdomen is more or less sharply defined from the rest of the body. In worms, crustaceans and insects the brain lies in the head above the intestine, and two cords of nerve tissue extend downward from the brain on both sides of the throat and connect the brain with the main line of nerve fibres which extend in a double line down the middle of the lower side of the animal.

Both crustaceans and insects are probably descended from worm-like ancestors but while crustaceans have been developed mainly for life in the water, insects have become more complex and live mainly on land.

The body covering of a crustacean is tough, and rendered still harder by deposits of carbonate of lime, so that the animal is enclosed, so to speak, within its own skeleton. At the joints, however, the skin is flexible, allowing a certain freedom of movement. This

hard skin-armor of the body affords excellent attachment for the muscles, and it is well known that in proportion to their size insects and crustaceans are the strongest of all animals. It has even been calculated that if a man possessed muscles as strong in proportion as those of a flea he could readily leap over St. Paul's Cathedral.

Fig. 46. YOUNG ROCK-CRAB. From life, natural size. Showing the rapid enlargement that took place after the shell was moulted. The Crab had lost one of its nippers, but this was regenerated after the moult.

Being encased in a natural armor crustaceans can not grow at a uniform rate, but enlarge suddenly at the periods when the shell is shed. This occurs at fairly regular intervals, and the entire shell is shed, even the coverings of the eyes and part of the lining of the stomach being cast off. The creature is then soft and helpless, and usually remains hidden in some safe retreat until the body has expanded and the new shell hardened.

The appendages of crustaceans are of various sorts such as feelers, mouth parts, claws, legs, egg-carrying organs, swimming and breathing organs, and stalked eyes.

The *Crustacea* are divided into two sub-classes, the lowest called the *Entomostraca*, the barnacles and water fleas, have a variable number of body segments, and the appendages are usually forked, and are apt to be quite similar each to each. The higher sub-class called the *Malacostraca* includes the crabs, lobsters, shrimps, and sand fleas. Their bodies consist of twenty segments; five in the head, eight in the middle part of the body, and seven in the abdomen; and their appendages are apt to be dissimilar each from each.

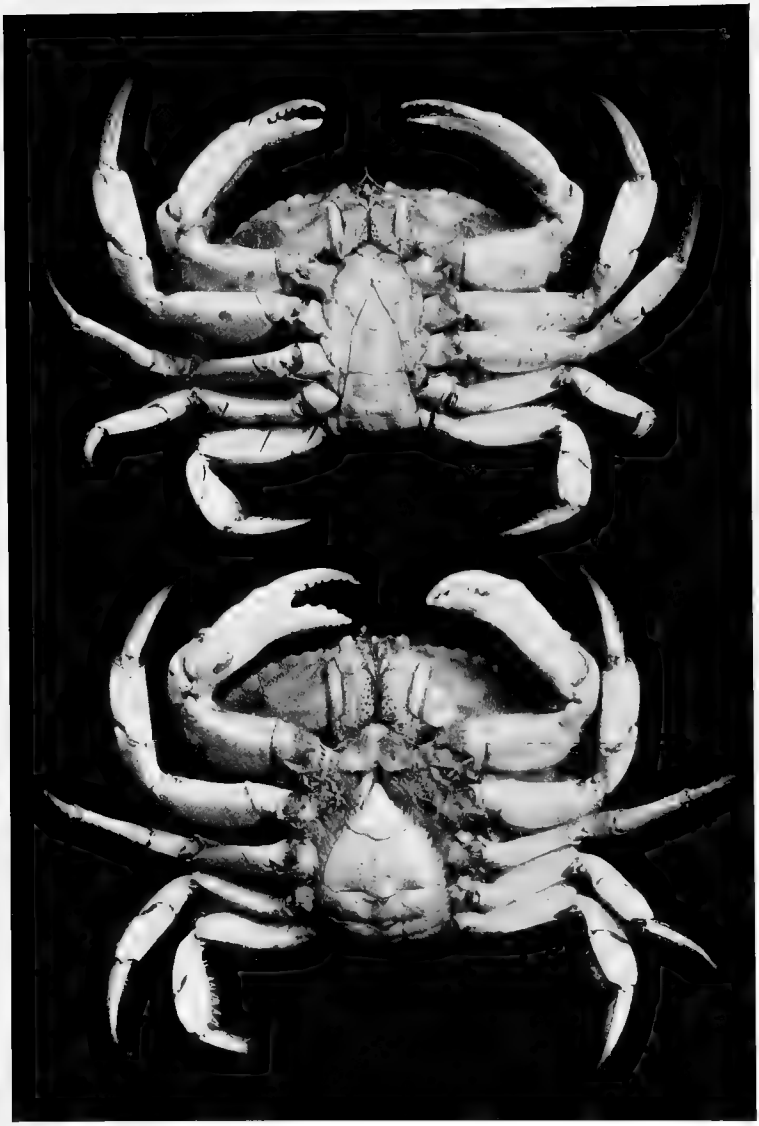

Fig. 47: ROCK-CRAB. Cape Ann, Mass.
Above: Male showing narrow abdomen.
Below: Female with broad abdomen that serves to cover and protect the eggs.

The eggs of crustaceans are often carried about attached to the abdominal appendages of the female. In the lower forms the egg usually develops into a more or less oval-shaped embryo called a *nauplius*, which has a single eye and three pairs of appendages. The first pair is simple and becomes the front feelers of the adult, while the other two pairs are forked, and become the second pair of feelers and the mandibles. In the higher crustaceans the eggs often contain so much yolk that the embryo is not set free until its development has gone farther than the nauplius stage. Good general descriptions of our crustacea are given in Arnold's "Sea Beach at Ebb-Tide;" Stebbing's "Crustacea," in The International Scientific Series, 1893; and Volume II of "The Riverside Natural History," edited by Kingsley.

THE BARNACLES

The older naturalists believed that barnacles were mollusks, but a study of their development showed that they are crustaceans related to the water fleas.

The egg of the barnacle is set free in the water and develops into a minute larva with a triangular shield over the back, a single eye immediately above the brain, a mouth, intestine and three pairs of appendages. The larva then moults a number of times, acquiring a pair of stalked eyes, and a pair of shells hinged along the back and projecting over the sides of the body. The first pair of appendages have now changed into organs of attachment which enable the little creature to fasten itself head-on to some rock or other suitable anchorage where it is destined to pass the remainder of its life.

A considerable change then comes over the creature. It remains without food while it develops a shell with hinged lids which may close or open the aperture. The barnacle has been described as a crustacean which is fastened by its head, lies on its back, and kicks its food into its mouth. If one watches a barnacle one will see how the feathery jointed legs are thrust out at regular intervals, and wave gracefully through the water to aerate the blood, and to set up currents which drive small creatures into the mouth of the barnacle.

Most of the barnacles are hermaphrodites, but in some genera

the males are minute, degenerate creatures without shells, mouth or intestines, and live within the shell of the female.

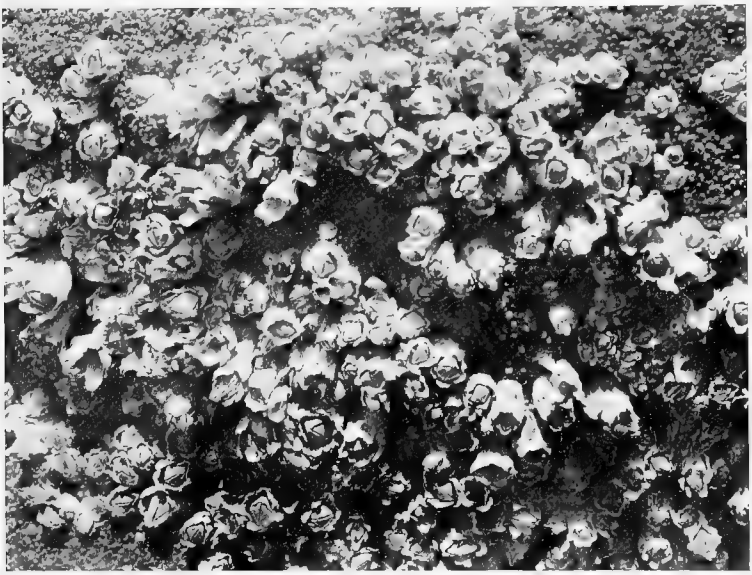

Fig. 48; Rock covered with Rock Barnacles. Cape Ann, Mass.

The Rock Barnacle, *(Balanus balanoides, Fig. 48)*, is found along the Atlantic shores of Europe and America, from the Carolinas northward. It lives only between tide levels, where it remains uncovered for a considerable period each half day, and is so abundant as to whiten the rocks. Individuals are crowded so closely together as to become distorted and elongated in shape. When the tide is out the barnacles remain closed up, but as soon as the water reaches them the lids of the shells open, and the delicate curling feet are thrust out at regular intervals, sweeping food into the hungry mouths of the barnacles. At the least shock or jar the barnacles close their lids with a snap and the waving motion ceases.

Fig 49a; Deep-water Barnacle growing upon a stone. From life. Cape Ann, Mass.

Balanus hameri, Fig. 49, is a large rough-looking, solitary barnacle that grows upon rocks below low-tide level off the coast of New England north of Cape Cod.

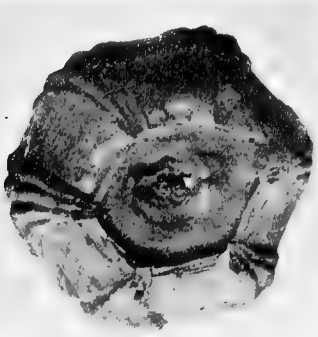

Fig. 50; WHALE BARNACLE.

The Whale Barnacle, *(Coronula diadema, Fig. 50)*, is attached to the skin of whales, the skin being drawn up into the shell of the barnacle so as to enable it to adhere firmly. The shell of this barnacle is fully an inch and a half wide and an inch high. In cross section it is hexagonal with six longitudinal ribs, each made up of four or five ridges. In barnacles that grow upon moving animals, the feathery feet are merely thrust out, and not waved about as in the rock barnacles, which must create currents in order to capture their food.

The Stalked Barnacles, *(Fig. 51)*. These are often called "goose barnacles," for the naturalists of the seventeenth century believed that geese hatched from them. They are usually found attached to floating objects, such as the gulf weed, drifting logs, pumice or buoys.

Fig. 51; STALKED BARNACLES, *Lepas Anatifera*. From a buoy at Tortugas, Florida.

The fleshy stalk by which the barnacle is attached is the head end of the creature, and the feathery, curling legs are seen to protrude now and again through a cleft in the side of the shell. There is a minute eye

attached to the side of the stomach. The shell is laterally compressed, and is made up of a number of calcareous pieces hinged

Fig. 52; AMERICAN LOBSTER. Cape Ann, Mass.

together. There are two common species of stalked barnacles in our parts of the Atlantic. One is called *Lepas fascicularis*, and is found floating in the Gulf Stream attached to logs and gulf weed. It is small, the whole animal, including the stalk, being usually not more than an inch in length. The shell is milky white, while the stalk and legs are rich brown. This species is often cast ashore upon our coast late in the summer.

Lepas anatifera, *Fig. 51*, is a larger and stouter species, fully two inches long. It is abundant upon buoys off the Florida coast, or upon ship's bottoms which have been in warm seas. It occurs in the tropical parts of all oceans.

The American Lobster, *(Homarus americanus, Fig. 52)*. We are all familiar with the general appearance of our lobster, but its habits are not so well known. It ranges from North Carolina to southern Labrador, and is now most abundant off the Maine coast. Years ago lobsters over 20 pounds in weight were not uncommon, but such monsters are now very rare. A specimen 30 pounds in weight and 42 inches long was, however, captured off the New Jersey coast in March, 1897. Our lobster is exceedingly variable in color, being usually dark green with red and blue mottlings;

but blue, red or cream-colored lobsters are sometimes seen. It is a great burrower, digging holes with its claws fully two feet deep, and then entering the burrow tail first. It feeds upon almost any dead animal it may find and will readily capture living fishes, or other marine animals, including young lobsters. These are torn to pieces in its large claws, and then still further ground up in the "gastric mill" or gizzard-like teeth of the stomach. Cod and other fishes destroy countless numbers of lobsters.

The eggs are usually laid in July or August, and adhere to the abdominal appendages of the female, while the great tail "fin," or telson, is folded forward so as to cover them. In this condition they are carried for about eleven months, so that they usually hatch between May 15th and July 15th. A female eight inches long will lay about 5,000 eggs, while one seventeen inches in length will produce fully 63,000. Individual lobsters do not spawn oftener than once every two years.

The little lobsters are about one-third of an inch long, and as transparent as glass, so that one may see their internal organs clearly. They immediately rise to the surface, and their feathered feet enable them to swim actively about. The claws are now very small, and the whole creature is shrimp-like in appearance. The little creatures swim at the surface for five or six weeks, devouring a great variety of minute animals, and not hesitating to bite off the legs of other young lobsters whom they may chance to meet. They moult six times and then sink to the bottom, and crawl into shallow water, where they remain hidden away under stones until autumn. On the approach of cold weather all of the lobsters crawl out into deep water, never going, however, to a depth much greater than 600 feet. They seem to prefer waters of a temperature of about 55° F. Professor Bumpus has shown that lobsters wander over the bottom to a considerable extent; one individual went twelve miles in three days.

Our lobster fisheries are worth at least $1,500,000 annually, but unless wise laws are soon enforced for their protection the ruthless persecution to which the lobsters have been subjected will practically exterminate them, in so far as commerce is concerned. No lobster under $10\frac{1}{2}$ inches in length should be sold, and no female carrying eggs should be killed. An excellent description of the

habits and life history of our lobsters, together with beautiful figures, are given by Francis H. Herrick in the "Bulletin of the

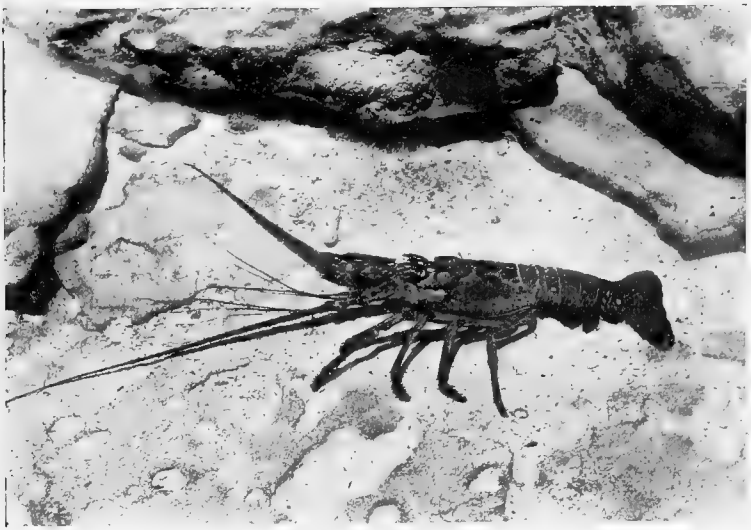

Fig. 53; SPINY LOBSTER. Tortugas, Florida.

United States Fish Commission," Vol. XV, 1895, and an estimate of their wandering habits, and the extent to which they are subject to destruction is given by Hermon C. Bumpus in the same publication, Vol. XIX, p. 225, 1899.

The Spiny Lobster, *(Panulirus argus, Fig. 53)*, is common in the Bermudas, Florida and West Indies, where it lives in rocky crevices in shallow water. It is highly esteemed in the market and appears also to be greatly appreciated by any wandering shark that can capture it It is often called the clawless lobster, for it has only five pairs of long delicate walking feet, which lack claws. The second pair of feelers is provided with sharp spines, and is stouter and longer than in our northern lobster. There are two curved sharp-pointed spines directed forward over the eyes, and there are also numerous short ones over the back and sides, especially near the forward end of the body. The creature is strikingly mottled with blue, rich yellow and brown, and there are a pair of

yellow eye-like spots on the sides of the second and sixth abdominal rings. The broad tail flappers are richly banded with blue, yellow and brown. This lobster is a timid creature, and relies upon its sharp spines for protection. If the feelers or legs be seized they are quickly thrown off, and then regenerate, developing only after the moults, when the shell is soft. It becomes fully two feet in length, and is an active swimmer, being enabled to dart rapidly backward by the powerful strokes of its large tail flappers.

Fig. 54; SNAPPING-PRAWN. From Coral Rocks at Tortugas, Florida.

A closely related species called *(Panulirus interruptus)* is found on the coast of California.

The Snapping Prawns, *(Alpheus).* There are about twelve species of these little lobster-like crustaceans which range on our coast from Brazil to Virginia. The largest are not more than one and three-quarters of an inch long. One claw is much larger than the other, and is provided with a sharp-edged blade which is normally held out at right angles to the claw. At the least alarm this blade is closed with a sharp snap reminding one of the explosion of a small torpedo. These little creatures live in crevices of coral reefs, under shells or stones, and fairly swarm in sponges; so that, when a sponge is lifted from the water it crackles as if filled with minute firecrackers. The report is so sharp that if one of these little prawns be placed in a glass aquarium jar, one is deceived into supposing that the glass has suddenly broken. They are inveterate fighters, and if two be placed in the same aquarium one or the other will quickly be dismembered and devoured. The eggs are carried about attached to the abdominal appendages of the female, and after hatching they swim through the ocean, and moult a number of times before assuming their final abode within a sponge or under dead shells, etc.

Alpheus saulcyi is a small species, from five-eighths to one and two-thirds inches long, which lives within sponges off the Florida coast and Bahamas. The body is translucent brown or green, and the upper surface of the great claw is vermillion.

Alpheus minus lives under dead shells, and is found on the North Carolina coast. It is about one inch long, and is quite translucent and uniformly dull green with dots of brown pigment.

Alpheus heterochelis ranges from the West Indies to North Carolina. In the north it is translucent green with the tail flappers tipped with blue and orange, while the upper surface of the great claw is very dark brownish-olive and blue. In the Bahamas, however, it is more transparent, and dotted with brown pigment. On the Carolina coast it lives in the beds of oyster shells, while in the Bahamas it is found under loose stones.

CRAYFISHES

The Crayfishes, or Crawfishes, resemble small lobsters, to which they are closely related, but they have never more than eighteen pairs of gills, while the lobsters have twenty.

Our crayfishes are abundant in fresh-water streams, ponds and rivers; none, however, are found in the eastern parts of New England.

The crayfishes east of the Rocky mountains have seventeen pairs of gills and belong to the genus *Cambarus*, while those of the Pacific slope, west of the Sierra Nevadas, have eighteen pairs of gills and are members of the genus *Astacus*. Curiously enough the European crayfishes also belong to the genus *Astacus*.

In Europe crayfishes are highly esteemed as food and are carefully cultivated, but in our country they are rarely eaten excepting in New York and New Orleans In view of the increasing rarity and high price of the lobster, it might now be found profitable to cultivate our crayfishes for the market. Their habits are closely similar to those of the lobsters. Some species live under stones, others prefer weedy streams while others burrow fully two feet into the mud, and will even live in swampy soil where the water is only to be found beneath the surface. Some of the mud-burrowing species construct chimney-like tubes above the entrance to the burrow, while at the bottom of the burrow there is a flask-shaped cavity filled with water. In common with the great majority of crustaceans, crayfishes are natural scavengers, and will eat almost any dead animal. They also capture living creatures, and will feed sparingly upon water plants. It is probable that under proper

feeding they could be rendered more palatable for market than when subsisting upon their natural diet. At present the fishery is worth not more than $2500 per annum.

An admirable description of the anatomy of the crayfish is given by T. H. Huxley in "A Manual of the Anatomy of Invertebrated Animals," 1891, p. 264; and also in the International Scientific Series, "The Crayfish," 1880.

Fig. 55; BROOK CRAYFISH. Orange Mountains, New Jersey.

In the neighborhood of New York we find three common species. In *Cambarus bartonii, Fig. 55*, the body is devoid of spines, but is pitted with little depressions scattered at fairly regular intervals. It is very abundant in running streams, and often hides away under stones or burrows into gravel. Large specimens may be three inches in length.

In *Cambarus blandingii* the body and claws are besprinkled with tubercles. It is dull greenish-brown, whitish beneath and lives in clear, running streams; often resting near the surface upon water plants, with its head pointed up stream. It grows to be over five inches in length.

Cambarus affinis is the crayfish which is commonly sold in the New York markets. It grows to be a little over four inches long, and the upper surface is mottled with darker and lighter shades of green, while the tips of the nippers are orange. The under surface is streaked with chestnut-brown It is common in the rocky beds of rivers, and often rests under flat stones, but avoids dense clusters of water plants.

SHRIMPS AND PRAWNS

These are generally smaller than the lobsters and crayfishes. Moreover, they are swimming creatures while lobsters and cray-

fishes are crawling forms. The forward part of the body is encased in a delicate shell called the carapace, while the abdomen is segmented and bends sharply downward instead of being in line with the carapace as in the lobsters. This gives a broken-backed appearance to the shrimps. The feelers, eye-stalks, legs and feathery gills are often remarkably long, and there are apt to be little claws on several pairs of legs. The last two segments of the abdomen bear flapper-like appendages which constitute a powerful swimming organ. While the shrimps are most abundant in shallow water along the seacoast, there are also many deep water forms, and a few live in fresh water. They feed upon both animal and vegetable matter, and are themselves devoured by hosts of fishes and other marine animals. Shrimps possess a delicate flavor which renders them a favorite food, and almost all of the large species are sold in the markets. The shallow water species are protectively colored, matching the bottom upon which they live, but the deep sea forms are some of them rich scarlet, and are especially distinguished by their very long, delicate antennæ and appendages, which probably serve as organs of touch in feeling their way over the dark floor of the ocean.

Fig. 56; COMMON SHRIMP. From Life. Cape Ann, Massachusetts.

Shrimps are known to science as the *Schizopoda.* This name is given on account of the forked appendages of the thorax, where the inner branch of each appendage is a jointed leg, while the outer fork is a feathered gill which projects freely into the water.

The Common Shrimp, *(Crangon vulgaris, Fig. 56)*, is found from North Carolina to Labrador, and from Alaska to California. It is especially abundant along the sandy shores of Chesapeake Bay and the coast of New England, north of Cape Cod.

The shrimp may be recognized by its broad, flat, scale-like expansions at the bases of the antennæ. It grows to be about two inches long, and is protectively colored, matching the bottom upon which it lives. It is extremely abundant in shallow water, but will

descend to a depth of about 300 feet. When disturbed it conceals itself quickly beneath the sand or mud, leaving only the eyes and

Fig. 57; SHRIMPS AND PRAWNS.

Above on right: *(Crangon vulgaris)*
Above on left: *(Crangon boreas)*
In the center: *(Pandalus annulicornis)*
To the right and middle below: *(Hippolyte sp)*
To the left below: *(Hippolyte pusiola)*
To the left of center: *(Mysis stenolepis)*

feelers exposed, and when the tide goes out it buries itself entirely. It spawns during the summer, and the young swim rapidly over the surface.

The Common Prawn, *(Palaemonetes vulgaris)*, is especially abundant in shallow brackish water, over muddy bottoms. It is found from Massachusetts Bay to Florida, but is rare north of Cape Cod. It becomes about one and one-half inches long and can be

distinguished from *Crangon vulgaris* by the sharp-pointed, saw-edged spine which projects forward between the eyes, its longer and more delicate feelers and slender legs. It makes a good bait for fishes, but is too small to be very valuable in the market.

Fig. 58; SOUTHERN OR EDIBLE SHRIMP.

The Edible Shrimp, *(Penæus setiferus, Fig. 58)*, is the prawn or shrimp of the southern markets, where it is highly esteemed as food. It becomes at least six inches in length and ranges from Virginia to Texas. It appears in shallow bays and estuaries in the spring, and spawns during the summer so that the young are commonly found along shore early in the autumn. *Penæus setiferus* may be recognized by its long, saw-toothed spine which extends above the back and projects forward between the eyes. This ridge is bordered on both sides by a deep groove which extends about half way down the back. In another and rarer species called *Penæus brazilensis* these grooves extend down the entire length of the shell. This form extends from New York to Brazil, and it often ascends rivers, living even in fresh water. Both species are protectively colored being more or less translucent brown, or mottled. The feelers are about a foot long and there are small claws at the ends of the first three pairs of feet. The southern shrimp fishery is worth more than $100,000 annually.

The Coral Shrimp, *(Stenopus hispidus)*. This beautiful shrimp is white, with three bands of bright scarlet across the body and four across each of the clawed arms. The body is about three inches long and is covered with short, sharp spines. The feelers and clawed

legs are slender and about five inches long. This shrimp ranges from New York to Brazil, but is found also among the tropical islands of the Pacific. It lives among the corals, the male and female swimming side by side. The eggs are of a delicate green color, and are carried about attached to the abdominal appendages of the female. When disturbed the shrimp retreats within the crevices of the corals.

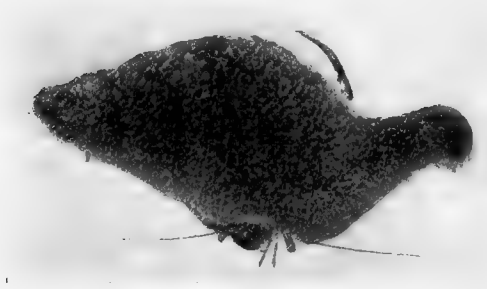

Fig. 59; HERMIT CRAB. From Life. Showing the borrowed shell covered with sea weeds and *Hydractinia*. Cape Ann, Mass.

The Feather-Footed Shrimp, *(Mysis stenolepis, Fig. 57)*, is a little translucent brown creature about one-half an inch long and may be recognized by the feathery hairs on its legs and antennae, large eyes, and spines on the sides of the body. It has no claws, and the abdomen is "broken-backed," and somewhat longer than the forward part of the body. It is most abundant on our coast in winter in shallow muddy or grassy places, and often occurs in great swarms.

HERMIT CRABS

The Hermit Crabs, *(Paguridæ)*. In these animals the abdomen is soft and covered only by a delicate skin, but the crab protects it by inserting its abdomen within the cavity of some empty shell which it drags about in all of its wanderings. This habit of occupying shells has profoundly modified the structure of the body. The abdominal appendages are reduced or wanting, and the sixth pair have become hook-like, allowing the crab to anchor itself within the shell. The abdomen is twisted so as to fit into the coils of the shell, while in some species all of the legs on one side are shorter than those of the other, thus giving the body a one-sided appearance. The front legs and claws of the crab are covered with a hard crust, and the eyes are mounted upon long stalks. When disturbed

the crab instantly withdraws within its shell, completely closing the opening with its claws, which are of the exact shape required for the purpose.

As the crab grows it must occupy larger and larger shells. These are apparently selected with considerable care, but having decided upon it the crab finally darts into its new abode with almost incredible rapidity. In common with other crustaceans these crabs are scavengers. They are also inveterate fighters, and will conquer and devour one another when opportunity offers. A number of marine animals grow upon the shells, which are carried about by hermit crabs, thus obtaining the advantages of a wandering life. Several species of hydroids, such as *Hydractinia*, cover the shells with soft, pink-white, velvety-looking growths, while a number of sea anemones also live upon the shells. One of these called *(Epizoanthus americanus)* finally dissolves the shell, forming a cavity within which the crab continues to reside.

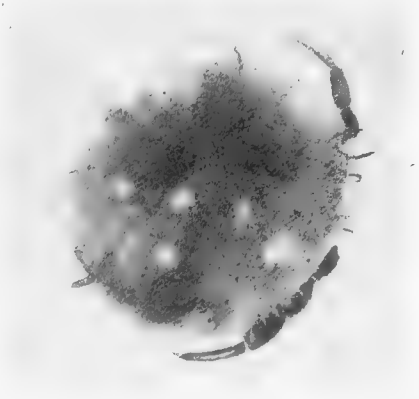

Fig. 60; HERMIT CRAB. From Life. Showing the borrowed shell covered with sea weeds and *Hydractinia*. Cape Ann, Mass.

Fig. 61; HERMIT CRAB. From Life. Cape Ann, Mass.

One of the most interesting of the hermit crabs is the Robber Crab *(Birgus latro)* of the tropical Pacific Islands. It is about two and a half feet long, and the abdomen is soft below but protected above by hard plates. It lives within deep burrows, and only occasionally visits the water. It crawls to the top of the cocoanut trees, and tears open the nuts for the sake of the white "meat."

Our hermit crabs carry their eggs about attached to the hairs of the lower side of the abdomen. The larvæ, which swim freely

Fig. 62; Hermit Crab removed from shell. Cape Ann, Mass.

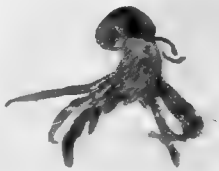

Fig. 63; Little Hermit Crab removed from shell. Cape Ann, Mass.

through the water, have a long spine fully twice as long as the body itself, projecting straight forward above the eyes. A forked spine also projects backward, so that the body of the crab appears as if attached to a long, forked stick. After a few moults its form changes, and it seeks the shelter of a small shell.

Three species of hermit crabs are found in shallow water along our coast:

Eupagurus bernhardus, Figs. 60–62, is common north of Cape Cod, and is hairy and bright red in color. In Europe it is used as bait by fishermen. It extends from shallow water to a depth of at least 300 feet.

Eupagurus pollicaris ranges from Cape Cod to Florida, and is abundant upon oyster beds and rocky bottoms of Long Island Sound. It is pale red in color and the claws are granulated rather than hairy. It inhabits the largest shells, such as those of the whelk, but appears not to be very fastidious, for the writer found one occupying the bowl of an old clay pipe.

Eupagurus longicarpus, Fig. 63, is the most abundant and smallest of our hermit crabs, and occurs in very shallow water. It may be recognized by its dull yellowish-white legs streaked with dull slatey-gray or blue.

The Sand Bug, *(Hippa talpoida, Fig. 64)*. This curious little creature is related to the hermit crabs, but no one would suppose this to be the case without careful study, for its appearance is

wholly different. It is oval in outline and about two and one-half inches long. The back is arched and covered with a smooth, hard,

Figs. 64; SANDBUG. Southern Shore of Long Island.

yellowish-white shell. The abdomen is broad, and is folded forward along the under side of the body The principal feelers are curiously feathered, and are often carried curled back against the sides of the body. The eyes are minute black specks at the ends of a pair of long, slender stalks.

This creature lives in shallow water along sandy beaches. It is very active, and swims and burrows with great rapidity. It is

Fig. 65; MANTIS SHRIMP. From a specimen in the New York Aquarium.

quite common along the hot, sandy shores of New Jersey and Long Island, and makes a good bait for fishes.

The Mantis Shrimp, *(Squilla empusa, Fig. 65).* This is often called the Mantis shrimp on account of the more or less general resemblance between its claws and those of the Praying Mantis.

It becomes about ten inches in length, and lives in long, winding burrows below low tide level. It extends from Florida to Cape Cod. The carapace, or back shield, of the creature is short and soft, while the abdomen is about three times as long as the carapace and is broad, flat and segmented. The large pair of feelers end in three branches, while at the base of each of the small feelers there is a broad, flat scale having its edges fringed with hairs. The eye-stalks are curiously bent, and project above the head. The last joint of the great claw is bent forward over the second joint, and is armed with six sharp spines which fit into corresponding sockets at the bottom of a groove on the outer side of the second joint. This constitutes a formidable weapon, and serves in the capture of many sorts of marine animals upon which the *Squilla* feeds. There are three pairs of weak walking legs which arise from the first three segments of the abdomen. The leaf-like, hair-edged gills, are seen attached to the lower surface of the abdominal segments. The posterior end of the body is blunt but beset with sharp spines, while a pair of spiny jointed flippers arise from each side.

The *Squilla* is an active creature, and when seized it makes effective use of its sharp claws and tail spines, and will inflict a painful wound. It is very attractively colored, for the body is pale green, each segment being bordered posteriorly with dark green and edged with bright yellow. The tail is tinged with rose color and mottled with yellow, green and black. It is nocturnal, remaining hidden away in its burrow during the day, and wandering about at night in search of prey. The eggs are laid within the burrow and a current of water is made to flow over them by fanning with the abdominal appendages. The transparent larvæ are found, during the summer, swimming at the surface. In the Mediterranean and tropical Pacific various species of *Squilla* are highly esteemed as food. The species eaten in Tahiti is the most delicately flavored crustacean the writer has ever partaken of, and it is possible that our *Squilla* may also be palatable. Certainly the large species of the Florida coast and Bahamas bears a close resemblance to the edible one of Samoa and Tahiti.

THE SAND FLEAS

These little crustaceans live upon our beaches, remaining during the day in burrows under heaps of decaying sea weeds upon

which they feed. They are agile animals, leaping with remarkable rapidity. In swimming they often progress on their sides or upon their backs with feet upward. They are creatures chiefly of the shore or of shallow water, although some closely related species are found in the deep sea. These minute animals are important scavengers, rapidly devouring all dead fishes and other forms of decaying animal or vegetable matter. They are themselves devoured in immense numbers, often by the identical species of fishes upon whose dead bodies they themselves delight to feast.

Fig. 66; SAND FLEAS. *Above: (Talorchestia longicornis). Below: (Orchestia agilis).* Long Island Sound.

Orchestia agilis, Fig. 66, is the common olive green or brown Beach Flea of our coast. It grows to be not more than half an inch long, and lives during the daytime under masses of sea weeds which have been thrown up upon the beach. It constructs burrows in the sand under the debris, and when disturbed it leaps with remarkable strength and agility.

A still larger species is, *(Talorchestia longicornis Fig. 66),* which is white or gray in color, and about an inch long. It is also a beach scavenger, and devours decayed sea weeds, feeding mainly at night, and remaining hidden within its burrow during the day. It appears never voluntarily to enter the water but is a good swimmer.

The Wood Borer, or Gribble, *(Limnorea lignorum),* is related to the sow-bugs and pill-bugs and belongs to the sub-order of *Crustacea* known as *Isopoda.* The gribble extends from New York to Nova Scotia, and is also abundant on the northern coasts of Europe. It is not more than one-fifth of an inch long, and has a flattened body with fourteen segments, and seven pairs of short legs. The back is covered with short hairs to which foreign substances are apt to adhere. It is dull gray in color and resembles a pill-bug, the similarity being still further enhanced by its habit of rolling up into a ball when disturbed. It can also leap and swim rapidly. This creature is most destructive to all submerged timber, devouring every

sort of wood excepting teak. It burrows through the softer parts of the wood, completely honey-combing the logs so that the knots and hard parts project. Submerged timber decreases in diameter at the rate of about an inch per year due to the ravages of this pest. Fortunately, however, it does not occur in any considerable numbers much below tide level. Submerged wood must be sheathed in copper or frequently painted with creosote or poisonous substances, in order to prevent its destruction.

CRABS

Brachyura.

The crabs are the highest of the *Crustacea.* The head and middle part of the body are covered with a shell which is usually broader than long. The abdomen is small, and is folded forward, fitting into a groove on the lower surface of the animal. In the male the abdomen is narrow, and has only two pairs of appendages, while in the female it is much broader, and has four pairs of appendages which serve to carry the eggs (see Fig. 47, Page 79). The two pairs of feelers are small, and the eyes are mounted on movable stalks which may usually be folded back into appropriate sockets. The mouth appendages are broad and flat so as to cover the opening of the mouth itself. The first pair of legs have pincers, while the following four pairs lack pincers but are formed for walking or clinging; the hindermost being often paddle-shaped and used in swimming. The plumed gills are contained in side chambers enclosed by the shell of the middle part of the body. Being thus protected from drying, many of the crabs may live for long periods of time on land, their gills remaining moist. Crabs live in both salt and fresh water, and at all depths. Some are active swimmers or crawlers while others are sedentary or even parasitic. They are scavengers, devouring almost any dead and decaying animal or plant. Despite their unclean habits, many species are highly esteemed as food, and crab fisheries are of great commercial importance. When hatched from the egg, crabs are totally unlike their adult form, and are said to be in the *Zoœa* stage. The head and middle part of the body are covered with a delicate shell which gives rise to four long, sharp spines. One of these is directed

forward and downward between the eyes, another rises from the centre of the back, and two others from the side near the middle of

Fig. 67; BLUE OR EDIBLE CRAB. Long Island Sound.

the body. The abdomen is long, and is not folded back under the body but projects freely. The little creature has a pair of stalked eyes and swims rapidly near the surface. It then moults a number of times and changes into what is called the *megalops* stage, in which it resembles a little crab excepting that the abdomen is stretched straight out, and not bent forward under the body as in full grown crabs.

The Blue or Edible Crab, *(Callinectes sapidus, Fig. 67)*, is the common crab of the markets, and it ranges from the Gulf of Mexico to Cape Cod. Very closely allied species are also found in the West Indies, on the African coast, and in the Pacific. Our crab fishery is worth more than $320,000 per year to the fishermen themselves. While we are sufficiently familiar with the general appearance of the blue crab, an account of its habits may be interesting. It delights in shallow bays and estuaries where the bottom is muddy and covered with eel-grass, and the water may be brackish. Here the crabs live during the summer, but in winter they retire to deeper places. They feed upon dead or live fishes

and many other marine animals. In fact, almost any decomposing animal will be greedily devoured by crabs. The shell is shed at

Fig. 68; GREEN CRAB. Annisquam, Mass.

least once during the summer and the crab then expands considerably, but remains soft for a few days, and is then sold in the markets as a "soft-shelled crab." The soft-shelled male crabs hide away during this period, for they are quite defenceless, but the soft-shelled female is protected by a hard-shelled male who clings to her. The paddle-like expansions of the last joints of the hindermost pairs of legs enable the blue crab to swim rapidly, while its other legs are used in crawling. It is exceedingly pugnacious and makes effective use of its sharp, powerful claws.

The eggs are laid during the summer soon after the annual moult, and are carried about attached to the abdominal appendages of the female until they hatch.

This blue crab can be at once distinguished from all other species of our coast by the sharp spine which projects outward from each side of the body. It becomes fully six inches in width.

The Green Crab, *(Carcinus mœnas, Fig. 68).* This crab is dark olive-green mottled with yellow-green, and is abundant in Long Island Sound, and on the New England Coast north of Cape Cod. It is also found on the northern coasts of Europe, where it is sold

in the markets. In this country it is used only for bait. It grows to be about three inches in width, and two in length. There are ten sharp-edged teeth, five on each side, which project forward from the front edges of the shell. The right hand claw is somewhat larger and blunter than the left. It is a pugnacious fighter and rapid runner.

Fig. 69; LADY CRAB. From a specimen in the New York Aquarium.

The Lady Crab, *(Platyonichus ocellatus, Fig. 63)*, is a beautiful species common on sandy bottoms from Cape Cod to Florida, and is abundant on the southern Long Island coast. It is of a delicate greenish-yellow profusely spotted with purple-colored rings. The powerful claws are armed with jagged teeth which enable the crab to seize upon the fish and other animals which it devours. This crab is often seen partially buried beneath the sand with only the eye-stalks protruding. The hind legs are paddle-shaped and the crab uses them very effectually in swimming, although it can also crawl with its other legs. It grows to be about two and a half inches long and three broad. The Gulf-Weed Crab, *(Portunus sayi, Fig. 70)*, lives within the masses of gulf-weed *(Sargassum)* which float over the tropical Atlantic, and is sometimes drifted upon our coast

Fig 70; GULF-WEED CRAB. From floating Gulf-weed. Tortugas, Florida.

late in the summer. It is mottled in brown and dull yellow, and matches its surroundings so perfectly when upon the gulf-weed, that its discovery is practically impossible unless the weed be taken from the water and shaken. The crab has paddle-shaped posterior legs, and is a good swimmer, its side-legs being long and oar-like, and fringed with delicate hairs. It becomes about one inch long and one and three-quarters wide. A spine projects from each side of the shell, and the pincers, although weak, are sharp.

Another little square-shaped crab called *Planes minutus* lives also among the gulf weed, and legend has it that when Columbus first saw this crab he reassured his timorous crew by stating that land could not be far away. The crab, however, never visits the land, but spends its entire life upon the ocean.

The Mud Crabs, *(Panopeus, Fig. 77, page 109).* These are small dark olive-brown crabs with large powerful claws and with sharp pointed legs adapted to crawling. They are abundant in Long Island Sound, but extend from the tropics to Massachusetts Bay. The name "mud crab" is indicative of their fondness for muddy shores, where they live under stones or in burrows within muddy banks or marshes. There are several closely allied species which have been carefully separated and described by J. E. Benedict and Mary J. Rathbun in "Proceedings of the U. S. National Museum," Vol. XIV, 1891, p. 355. Pls. XIX–XXIV.

A common mud crab of Long Island Sound is *Panopeus herbstii, Fig. 77*, which ranges from Brazil to Rhode Island. It lives within burrows in moist, muddy banks or under stones on muddy bottoms. It becomes one and one-half inches broad, and is dull brown-green in color. A smaller species with a flat-backed shell, only about three-quarters of an inch in width, is *Panopeus depressus.* It may also be distinguished by its black-colored nippers.

The Rock Crab, *(Cancer irroratus, Fig. 71)*, is the common crab of the New England coast north of Cape Cod, although it ranges from South Carolina to Labrador. It is most abundant a little below low tide level but also lives between tides, where it is usually found under stones, in rocky crevices or buried beneath the sand when the tide is out. Above it is dull brick-red in color speckled over with small brownish spots, while the under parts are yellow. Seen from above the shell is oval without sharp points at the side, but

Fig. 71; Above: JONAH CRAB. *Below:* ROCK CRAB.
Cape Ann, Massachusetts.

with nine blunt, smooth-edged teeth along each side of the front edge. The claws are sharp but powerful. This is a crawling crab, and all the legs end in a sharp spine, there being no paddle-like swimming feet. The crab is closely related to the edible crab of England and France but, while it is sold in our markets to a limited extent, it is not highly esteemed. The shell grows to be three inches long and five wide. The eggs are carried about by the female during the summer and hatch as little spined larvæ which swim at the surface and soon moult and change into little creatures which resemble the adults, excepting that the abdomen projects straight out in a line with the shell instead of being folded under; and there are short spines on the shell which are not seen in the adult. After again moulting several times, the larva becomes a little rock crab.

The adult rock crabs moult in winter, and are then sold in the New York market as soft-shelled crabs, although they are not to be compared with the more highly esteemed blue crab.

The Jonah Crab, *(Cancer borealis, Fig. 71)*, is closely related to the rock crab, but can be distinguished by its rougher shell, and the saw-edged teeth on its front edges. It becomes larger than the rock crab, and ranges from the eastern end of Long Island to Nova Scotia. It lives on rocky shores exposed to the wash of the breakers, and does not hide away under stones as does the rock crab.

The Oyster Crab, *(Pinnotheres ostreum, Fig. 72)*. The female of this crab lives, when mature, within the gill cavity of the oyster, and is highly esteemed as a delicacy, being sold in the markets at a high price. In the female the shell is pinkish-white in color and very thin, and the legs so weak that the creature could not survive away from the protecting oyster. The crab does not devour the oyster, but merely lives in association with it. The male crabs, however, swim freely over the sea, and they are brown in color with a light colored central stripe, and four whitish spots. They are smaller than the females, and their shells are hard. The case of the oyster crab is interesting, for, while the male has remained active, and has retained a hard shell and strong claws and legs, the female has lived a protected life, and her shell has degenerated into little more than a soft membrane, while

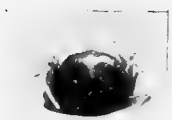

Fig. 72; FEMALE OYSTER CRAB. Long Island Sound.

her legs and claws are now too weak to be of any service in the battle for life outside of the cavity of the oyster shell. The eggs are carried by the female until they hatch. The larvæ then swim through the water, and the little females enter oysters in their last larval stages.

Another little crab *(Pinnotheres maculatum)* is found within the cavity of the shells of the common mussel, and the scallop.

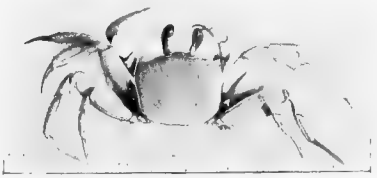

Fig. 73; GHOST CRAB. Florida Beaches.

The Ghost Crab, *(Ocypoda arenaria, Figs. 73, 77)*, ranges from Brazil to New Jersey. The young are often found late in summer on the hot sandy beaches of the southern coast of Long Island, although they probably die in the winter. The shell of the crab is about two inches wide and a little less than this in length, and is quite rectangular with an angular ridge along each side. The eyes are mounted on the ends of long stalks, which are usually held upright, but may be folded back into sockets on the face of the shell. The crab is dull yellowish-white, and the surface of the shell is granulated. The claws are sharp and powerful, one claw being about twice the size of the other. This crab digs long inclined burrows fully three feet deep into the sandy beaches. It scrapes the sand out "sidewise" with its legs and throws it away from the mouth of the burrow by a sudden dash. It is a scavenger, feeding upon decomposing animals and plants, and even eating beach-fleas. Although these crabs are relatively inactive during the day, at night they swarm in great numbers over our southern beaches. As they flit rapidly about in the moonlight their popular name of ghost crab seems remarkably

Fig. 74; FIDDLER CRAB. *Male*, Long Island, N. Y.

appropriate. As one approaches they dash off with great rapidity and will often rush into the water, although the gray snappers are

Fig. 75: Burrows of Fiddler Crabs. In the center of the cut a male crab may be seen emerging from its burrow. Streets of Key West, Florida.

swimming close along the shore in order to devour them. The crab rarely enters the sea excepting during the breeding season, in the spring of the year.

Mr. Beebe of the New York Zoological Park discovered that this crab is very destructive to the eggs of sea birds on Cobb Island.

FIDDLER CRABS.

Fiddler Crabs, *(Uca, Figs. 74, 75)*. These crabs live in immense numbers on muddy banks above high tide, and literally riddle the ground with burrows into which they rush for shelter at the least alarm. In the male one claw is very large while the other is small, but in the female both claws are small and of equal size.

The eyes are mounted upon long, movable eye-stalks. These crabs feed upon plants, the male using his small claw, and the fe-

male both of her claws for the purpose. They often scrape up pellets of algæ from the muddy surface of the ground, and carry these into their burrows for food.

They can remain out of water, if the ground be damp, for months at a time, and are exceedingly pugnacious, walking "sideways," usually with the great claw forward. In the construction of its burrow the crab uses its walking legs to scrape out the mud. This mud is then rolled up into little pellets, and dragged to a considerable distance from the mouth of the burrow; the crab all the while appearing exceedingly wary and moving its eye-stalks about in all directions. In emerging from the burrow the great claw is usually thrust out forward, whereas it is the last part of the crab to be drawn in in entering. There are three common species on the Eastern coast of North America:

Uca pugnax, *Fig. 74*, burrows into salt marshes, completely riddling the muddy banks with its holes. It ranges from Provincetown, Massachusetts, to Georgia, but a close variety is abundant in the West Indies and Gulf of Mexico. The holes are about three-quarters of an inch in diameter, and two or more feet in depth.

Uca minax is the largest of our fiddler crabs, and can be distinguished by the red spots at the joints of the legs. It digs its burrows along the banks of rivers or brooks where the water is only slightly brackish or even fresh. It often constructs an oven-like archway of mud over its burrow, thus providing itself with a safe place of look-out for enemies. It ranges from southern New England to Florida.

Fig. 76; ORCHID LAND CRAB. Loggerhead Key, Tortugas, Florida.

Uca pugilator digs its burrow in sandy or muddy beaches from Cape Cod to Florida. It can be distinguished by its rectangular outline and the highly polished surface of the back of the shell.

The Orchid Crab, *(Gecarcinus lateralis, Fig. 76)*, is a land crab, and literally swarms over many of the Florida Keys and West Indies. It is also found at the Bermudas, and on the coast of South America. The shell is about two inches wide and a little less than this in length, with smooth, rounded edges. The central parts of the back are dark purple—almost black, while the sides of the shell and the large claws are rose-red. The walking legs and under parts are dull yellow. This crab spends almost its entire life upon land, the gills being small and enclosed in large chambers which admit air but maintain the cavity moist. The creature lives under damp logs or leaves, or digs burrows fully three feet in depth; and is often found fully twenty feet above high tide level.

It is mainly nocturnal, and great numbers of them crawl about during the night seeking all manner of refuse and carrion upon which they feed. In the spring they all visit the ocean to breed, and in midsummer they retire to the depths of their burrows to moult. The crab is a fairly rapid runner and an excellent climber. It is also a pugnacious fighter, being well protected by its very hard shell.

The Spider Crabs, *(Fig. 77)*. These are sluggish, weak-clawed crabs with remarkably long, slender legs. Their bodies are usually flask-shaped with long, tapering snout, and short eye-stalks. Although apparently stupid, these crabs have what is probably the most highly developed nervous system found in the crustacea, for the ganglia of the body are often united into a single disk-like brain.

Many of the spider crabs have the habit of placing bits of seaweed, hydroids and other marine growths upon their backs, so that the crab is completely hidden under a veritable marine garden. It has been found that the crab deliberately bites off fragments of weeds, chews them for a time and places the weeds upon its own back, where they are caught by the saw-edged or hooked-hairs of the crab's back, and probably also anchored by means of adhesive mucous from the crab's mouth. The crab always covers itself with the sort of weeds, etc., found in its immediate vicinity, and if removed to another situation, the appearance of which is different, promptly removes the old weeds and replaces them with those which match the new surroundings.

One of the spider crabs *(Macrocheira kämpferi)* is the largest

living crustacean, for the spread of the legs is fully 12 feet. It lives off the coast of Japan at depths greater than 600 feet, and is occasionally entangled in the set-lines of the fishermen.

Our largest spider crabs are *Libinia dubia*, *Fig. 77*, and

Fig. 77; Above: MALE SPIDER CRAB.
Left: FEMALE SPIDER CRAB.
Right: GHOST CRAB.
Center: MUD CRAB.

Libinia emarginata. They resemble each other closely, and the legs of both spread about eighteen inches, the males being larger, and having longer and stouter legs than the females. *Libinia emarginata* has more spines on its back than *Libinia dubia*. Both live from Cape Cod to the Gulf of Mexico, but *Libinia emarginata* extends north of Cape Cod to the coast of Maine, and lives usually in deeper water than *Libinia dubia*. *Libinia dubia* is very

abundant in Long Island Sound on seaweed-covered bottoms, where it attains its maximum size. The backs of these crabs are covered with hairs, and sea weeds, barnacles, and hydroids often grow upon them. They are used only for bait.

The Toad Crab, *(Hyas coarctatus)*. This is a spider crab but its body is relatively large and the legs slender and weak. It spreads over not more than two and a half inches, and the back and legs are often densely covered with seaweed which the crab affixes to its body. It is abundant in shallow, rocky tide-pools from the Arctic Ocean to New Jersey, but lives also in deep water off the coast, where it crawls over rocky bottoms, and provides food for cod and other fishes. It is the commonest spider crab along the New England coast north of Cape Cod.

The Horseshoe Crab, *(Limulus polyphemus, Fig. 25)*. This common animal lives in shallow water along our coast from Yucatan to Maine, and is often called the king crab. It is, however, not a crab but is probably a descendant of the long extinct trilobites, and there is reason to believe also that it is related to the spiders and scorpions. It lives off muddy or sandy shores, and is often seen slowly gliding over the bottom or half buried within the mud. The shell over the head and trunk is crescent-shaped, smooth and dome-like with two valley-like furrows along the sides of the back. The large lateral eyes are easily seen, but if we look more closely we will also see two little median eyes farther forward. Altogether the appearance of the head region of the horseshoe crab is quite similar to that of the trilobites which died out in the age of the coal, although the trilobites probably had no median eyes. The abdomen of the horseshoe crab tapers rapidly backwards and is composed of six fused segments ending in a long, sharp, movable spine, so that the animal is about one foot broad and two feet long. The females are larger than the males. There are seven pairs of legs. The first six end in nipper-like claws while the seventh gives rise to a whorl of oar-like flaps used in pushing the creature over the bottom The five pairs of appendages of the abdomen are leaf-like, and serve as gills and for swimming. In late spring and early summer the horseshoe crabs come up in pairs upon the beaches, and deposit their eggs in holes which they scoop out in the sand and leave for the waves to fill. They

are especially abundant upon the beaches at the times of the spring tides. The eggs hatch in about a month, and the young bear a remarkable resemblance to the trilobites so that they are said to be in the trilobite stage. The sharp terminal spine develops later, after moulting.

Horseshoe crabs have been used for making fertilizer in Delaware Bay and are nearly exterminated in that region. They are among the most interesting of all marine animals, and are probably the last survivors of a race which may have been a connecting link between the trilobites, crustaceans, and scorpions. There are very few existing species, one being found on our coast and several on the coast of Asia.

THE SEA SPIDERS

Pycnogonidæ.

These are generally small creatures which crawl slowly over hydroids and sea weeds, and bear a superficial resemblance to spiders. Their true relationships are, however, a puzzle to naturalists.

The body is extremely small, so that the stomach and reproductive organs extend outward into the long, stout legs, the stomach in some species reaching even to the tips, while the reproductive organs open on the lower sides of the second joints.

There are typically seven pairs of appendages in the male and six in the female, the third pair being absent in the females of many species. In the male, however, these are developed into egg-carrying organs, for he gathers the eggs into balls as soon as they are laid, and fastens them to his third pair of legs by means of a cement which issues from openings at the fourth joints of his walking legs. When the young hatch they often crawl over the male in considerable numbers. In other genera the young enter the digestive cavities of hydroids, and form gall-like enlargements upon the stems, within which they live.

Phoxichilidium maxillare is a small species which varies in color from blackish-brown through sepia to almost white, and spreads about one inch. It is commonly found crawling over hydroids and sea-squirts, on shelly bottoms. The young live for a

time within hydroids, forming gall-like swellings. The legs are often sufficiently translucent to permit one to observe the wave-like contraction of the stomach-tubes within them.

An excellent account, accompanied by good figures of the sea spiders of our coast, is given by Edmund B. Wilson in the "Report of the United States Fish Commission" for 1878; and in "Transactions of the Connecticut Academy of Science," Vol. V.

MOLLUSKS.

ALTHOUGH mollusks include creatures of most diverse forms and habits, there are certain things which we may say of the race as a whole.

In the first place their bodies are not divided into segments, as is often the case in worms and crustaceans. Moreover, the right and left halves of the body are typically similar each to each, although this is not the case in forms having coiled shells. The lower surface of the body consists of a thick muscular foot used in creeping. In front of the foot we find the head, which may have a pair of eyes and tentacles; while the mouth lies on its lower surface and is often provided with numerous horny, rasping teeth. A flap-like fold of the body extends outward from the sides. This fold is called the "mantle," and its free edge and upper part secretes the shell which usually covers the back of the mollusk. The feathery gills arise from the sides, and lie in the space between the lower side of the mantle and the side of the body. The intestine is coiled and opens typically at the posterior end of the body, behind the foot. There is a paired digestive gland or "liver" which pours its secretion into the mid-gut. The three-chambered heart lies above the hind gut and pumps blood from the gills to other parts of the body. The simplest mollusks are the *Chitonidæ* or armadillo slugs, specimens of which are commonly found crawling over heaps of dead shells. Their bodies are flat and oval in outline, and the back is covered with eight shingle-like calcareous plates. The mouth is situated on the lower surface immediately in front of the broad muscular foot. A deep groove extends down each side of the body, and from the bottom of this arise the lancet-shaped gills. Chitons cling with great tenacity to the surface upon which they may be crawling, but if torn off they roll up into a ball.

A common species with us, about half an inch long, is *Trachydermon apiculata*, which ranges from Cape Cod to the Gulf of Mexico. It is abundant upon dead oyster shells and is usually dull brown or gray in color, although some specimens are white.

Acanthopleura granulata, *Fig. 78*, is a large chiton about three inches long, which is abundant on rocky shores, between tide limits, in the Bahama Islands and West Indies.

Another great group of mollusks are the snails, slugs and limpets, which are all grouped under the scientific name of *Gasteropoda*. In all of these the shell, when present, consists of a single

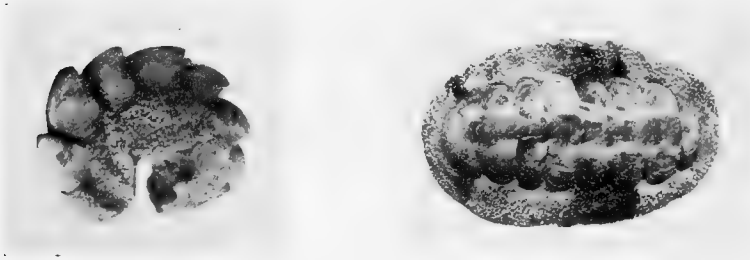

Fig. 78; Acanthopleura granulata the commonest Chiton in the West Indies. From Andros Island, Bahamas.

piece, not of a series of shingles, as in the chitons. In some *Gasteropoda*, however, the shell has become enclosed by an overgrowth of the edges of the mantle, and may even disappear in the adult state.

In snails we find that the viscera are protected by being covered with a spirally coiled shell, within which the entire foot and head may be withdrawn. Indeed, in many of the sea snails we find a horny or calcareous plate called the "operculum," which is developed on the upper side of the posterior part of the foot, and when the creature draws in its head and foot this completely closes the aperture of the shell. The operculum is very rarely seen in fresh water snails. The sea snails have at least one feathered gill, but the land and fresh water species have lost their gills and the mantle edge has fused with the side of the body, making a large, air-filled cavity which opens at one point, usually on the right side, and serves as a lung. One can easily see this breathing pore in slugs and fresh water snails, and the latter must come to the surface at regular intervals to let out a bubble of air, and take in a new supply. Slugs, land and fresh water snails are hermaphrodites, and may bring forth their young in a well developed stage, although

many species lay eggs. Many snails are herbiverous, while a few prey upon barnacles or other mollusks. Sense organs are poorly developed in snails, but in land snails and slugs we often find eyes mounted upon the tip ends of long tentacles which arise from the head. In sea snails, however, the eyes are smaller, and are found at the bases of the tentacles or only half way up.

The clams, oysters and mussels form a great group called the "*Lamellibranchiata*," for their gills project in curtain-like sheets from the sides of the body, within the shell. In these mollusks we find two shells or more properly "valves," one on the right and the other on the left side of the body, while the "hinge" between the valves extends along the back of the animal. This hinge is tough and muscular, and tends constantly to open the valves, but this is prevented by the contraction of two powerful sets of muscles which run across from one valve to the other.

The foot of the animal is often well developed and capable of pushing the creature rapidly through the sand, as in the razor-clam, while in other cases, as in the oyster, it is small and degenerate. There is no distinct head, but the mouth has two leaf-like lips. It should be said that the long, muscular "neck" of the soft-shell clam is not the neck of the animal, but is a tubular outgrowth of the mantle, which opens by two apertures. The one on the lower side is for the admission of water to the gill chambers, and the other is the anal aperture. A continuous current of water flows in at the former and out from the latter aperture. In scientific language the "neck" of the clam is called the *siphon*, and it is well to remember that it extends outward from the posterior end of the body; the mouth being at the opposite side of the shell.

Clams, oysters and mussels feed upon minute plant and animal organisms, which are drawn in between the edges of the mantle, or through the siphon by means of the constant beating of vast numbers of little hair-like cilia that cover the gills.

The most highly developed mollusks are the *Cephalopoda*, represented by the squid, octopus, nautilus, and argonaut. In these we find two large eyes and eight or ten long, muscular, sucker-bearing "arms" which surround the mouth. These arms constitute a portion of what was once the foot of the ancestral forms from which the *Cephalopoda* are descended. The remaining part

of the foot has become the tube-like "siphon," through which water is ejected from the large mantle cavity.

In all living forms except the nautilus, the shell is internal, although two of the arms of the female argonaut secrete a papery capsule which resembles a shell in appearance, but is only a brood pouch to hold the eggs, and is in no sense comparable with the shells of other mollusks. A more detailed account of the anatomy of the *Cephalopoda* will be given in the description of our common squid. All of the *Cephalopoda* are very active creatures, capturing fishes and other marine animals by means of their sucker-bearing arms, and crushing the prey in their horny beaks. They usually dart backward, being propelled by forcing the water from the mantle cavity out through the siphon, the opening of which is directed forward, but may be turned so as to drive the stream backward.

In the adult form the mollusks appear to be widely separated from all other groups of invertebrates; but a study of their development shows, that in their earliest stages they are worm-like in a number of important characters, and it seems probable that they are remotely descended from worm-like ancestors.

Good accounts of our mollusks will be found in Arnold's "Sea-Beach at Ebb Tide." Excellent figures and clear descriptions of the species of the New England coast are given by Gould and Binney, in "Report on the Invertebrates of Massachusetts," 1870, Wright and Potter, Boston; and the land shells are equally well described in "The Terrestrial Air-breathing Mollusks of the United States," by W. G. Binney, in Bulletin of the Museum of Comparative Zoology at Harvard College, Vol. IV, 1878.

CLAMS, OYSTERS, AND MUSSELS.

Lamellibranchiata.

In this great order of mollusks the shell is divided into two halves, or valves, each half shell covering a side of the body, while the hinge of the valves extends down the middle of the back of the animal. This hinge is an elastic cushion that tends to cause the valves to gape open, but this tendency is counteracted by one or two strong adductor muscles, that extend across from one valve

to the other. In the oysters and scallops there is but one adductor muscle, while in clams and mussels there are two. When the adductor muscles relax, the hinge-cushion causes the valves to gape;

Fig. 79; Mussels exposed at low tide. Annisquam, Mass.

and this is the normal condition while the animal is immersed and feeding. When the tide goes out, however, or the creature is suddenly disturbed the adductors contract, thus closing the valves.

The shell is secreted by a membrane called the mantle, that arises from the right and left sides of the mid-dorsal line and extends downward as a sheet on both sides of the body; the form of the sheet being similar to that of the shell it secretes. The outer edges of the mantle are thickened and are usually more or less fused, thus binding the two valves together along their edges. Definitely placed openings are, however, always found where the mantle edges do not fuse. One or two of these are opposite the posterior end of the body of the animal, and allow water to pass in and out of the mantle-cavity, while another on the ventral side allows the foot to be thrust out. In the clams the openings for the admission and expulsion of water are separated and the mantle is here ex-

tended as a long double tube, erroneously called the "neck," that projects outward from the posterior end of the shell. This neck should be called the siphon and if one observes a living clam it will be seen that a constant current of water is passing in through the opening in the siphon that is farther away from the hinge, and pouring out through the one nearer the hinge side. This current is caused by the beating in unison of myriads of cilia that cover the gills of the clam; and thus water is brought in to aerate the blood, and to provide the minute organisms upon which the clam feeds, while the waste water and products of excretion are carried away through the dorsal-most opening. But the mantle serves not only to provide definite openings for water currents. It secretes the horny outer skin, and the inner stony layers of the shell.

In all of the young and in the great majority of adult Lamellibranchs the two valves of the shell are exactly alike in shape, but in those which live attached to objects the valves are often dissimilar, as in the case of the oyster and the jingle shell *(Anomia)*.

The body of the Lamellibranch lies suspended within the mantle-cavity, being attached to the mantle along its dorsal edge. The mouth is near the dorsal side of the anterior end of the body, away from the siphon. It has no teeth, and is a deep groove bordered above and below by projecting ridges which function as lips.

The foot is a muscular expansion on the ventral side of the body. In some attached forms the foot is very degenerate, but in many of the clams it is developed into a strong blade-like organ, capable of great expansion and contraction, and serving to move the animal from place to place, to burrow, and in some forms even to swim. In many forms the foot is provided with a special gland that secretes a glue-like substance which adheres to anything it touches, and hardens into a tough, elastic thread serving to fasten the mollusk to an anchorage. This thread or rather accumulation of threads is called the *byssus*. The byssus may usually be cast off at will, and renewed thread by thread. By means of these threads, the mussels are able to drag themselves slowly about, or even to climb.

The most characteristic organs of Lamellibranchs are the sheet-like gills that arise from the sides of the body, and hang freely within the mantle cavity. Indeed the name *Lamellibranchiata* means

"plate gills," and the gills of a clam or oyster bear a close superficial resemblance to a pair of delicate leaves on each side of the body. In some of the lamellibranchs, however, the gills consist of delicate filaments calling to mind the barbules of a feather. Gills of this sort are seen in the jingle shell *(Anomia)*, the bloody clam and in mussels. In oysters and clams, however, the feathery filaments are fused one to another at many points, leaving sieve-like openings through which water may pass in its course through the gills. The gill sheets are also fused to the mantle, thus forming a chamber through which the waste water from the gills passes along the sides of the body on its way to the excurrent tube of the siphon. The water current over the gills is maintained by the orderly and constant beating of vast numbers of cilia that cover their surfaces.

Lamellibranchs feed upon minute organisms, both animal and vegetable. This food is drawn in with the water currents, and is caught upon the slime of the gills, and then driven toward the mouth by the movements of the cilia. There it is collected upon the curtain-like lips, and driven by their cilia into the alimentary tract.

There is a fairly well developed stomach which is surrounded by a large liver, the duct of which empties into the stomach. A long gelatinous rod called the crystalline stylet is often found in the stomach, but its exact nature and function are unknown. The intestine is twisted, and is surrounded by the genital organs.

The heart is three-chambered, and the hind-gut passes through it. It pumps blood from the gills to other parts of the body.

The *Lamellibranchiata* are sedentary creatures and many of them remain fixed from the end of their larval development until death, as is the case with the oyster. A few, such as the scallop, are enabled to swim in an awkward darting manner by the rapid closure of their valves, thus driving the animal hinge-side forward. Others, such as the clams, are enabled to burrow through sand and mud by means of their muscular foot, while still others, such as the mussels, drag themselves slowly about by means of their byssus threads.

As one would expect in such slow moving creatures, sense organs are poorly developed. On the mantle edge of the scallop,

however, we find tentacles, and also complex eyes each provided with a lens and a well developed retina which, curiously enough, bears a close general resemblance to that of the vertebrates, for it is turned inside out. Near the sides of the gills are organs that are believed to serve in tasting the water, and there is also a pair of primitive ear-like, or balancing, organs in the foot. Each of these consists of a cavity lined with cells which bear long hairs, while the interior of the cavity is filled with a gelatinous fluid, and contains one or more stony concretions, or even grains of sand. It is probable that these primitive ear-like organs enable the mollusks to perceive shocks and jars in the water, and it is certain that many of them are capable of perceiving sound.

The nervous system is quite simple and consists of three pairs of ganglia, or masses of nerve cells, joined by nerve fibres. One pair of ganglia is near the mouth and above the throat, another pair is at the base of the foot, while the hindmost pair is under the posterior end of the intestine.

The early stages in the development of clams, oysters and mussels, bear a general resemblance to those of certain groups of worms, and it seems probable that mollusks and worms are descended remotely from one and the same ancient stock, which is now extinct. The egg develops into a little pear-shaped larva closely resembling the tack-headed larva *(Trochophora)* of worms excepting that it is provided with a half-shell on either side. The little mollusk swims through the water until the shell becomes too heavy, and then it sinks to the bottom. A considerable number of young lamellibranchs attach themselves to objects by means of a byssus thread which is secreted by a gland in the foot. After growing older, however, they cease to develop a byssus, and change their habits. The young of the scallop, the long clam, and the pearl oyster form these byssus threads, while the well grown animal does not. The young of the fresh-water mussels are parasites, and bury themselves for a time beneath the skin of fishes.

A good general account of the structure of lamellibranchs is given in Arnold Lang's "Textbook of Comparative Anatomy," Part II, 1896, Macmillan Co.; and a systematic review by Woodward and Tait in "Woodward's Manual of the Mollusca."

All of the Lamellibranchs are aquatic, and the vast majority are

inhabitants of the sea. They differ greatly in size and shape, varying from microscopic dimensions to four and a half feet in width, as in the giant clam *(Tridacna gigas)* of the tropical Pacific and Indian Ocean. This great clam lives half buried in the coral reefs with the sinuous gape of its shell uppermost. It commonly remains with its valves slightly open, showing the rich, blue edges of the mantle, but if the tide retreats or if it be suddenly disturbed the valves close tightly. The animal, exclusive of its shell, often weighs twenty pounds and, although coarse, is sometimes eaten by the natives.

Excellent photographs showing these clams partially exposed at low tide are given by W. Saville-Kent in "The Great Barrier Reef of Australia," Plate XXIX.

The American Oyster, *(Ostrea virginica, Fig. 80)*, is found from the Gulf of St. Lawrence to Texas, but is most abundant in Chesapeake and Delaware Bays and in Long Island and Pamlico Sounds. It thrives best in shallow bays and estuaries where the water is apt to be brackish. Our oyster fisheries are worth $16,600,000 annually.

Oysters usually lie upon their sides, and the lower valve fastens itself to a rock or other firm anchorage by the shelly secretion of the mantle. This lower shell is almost always upon the left side of the body, and is quite deep and convex, while the upper shell is much flatter or even concave. At the narrow end of the shell we will see a dark brown, elastic hinge, which is so arranged that it tends constantly to cause the two valves of the shell to open, but this is prevented by a strong muscle that extends across from both sides of the oyster's body and binds the valves together. This strong adductor muscle is commonly but erroneously called the "heart." In the American oyster the place of attachment of this muscle to the shell is marked by a dark brownish-purple area while in the common *Ostrea edulis* of Europe this area is uncolored. When undisturbed, and under normal conditions oysters commonly remain with their shells gaping slightly open. The inside of the shell is lined with a delicate membrane called the mantle, which grows out from both sides of the mid-dorsal line of the body and secretes the shell itself.

There are also a pair of gills which arise from the sides

of the body, as two sheets on each side, near the mid-dorsal line, and which lie free in the space between the mantle and the body of the oyster. The digestive tract is much coiled and twisted, and the mouth of the oyster is placed close to the hinge at the narrow apex of the shell, where it is surrounded by curtain-like lips.

Fig. 80; AMERICAN OYSTER.

There is a well developed stomach which often contains a glistening, gelatinous, rod called the "crystalline style." The function of this is unknown, although it may possibly represent stored up nutrient material.

The large green-colored liver surrounds the stomach into which it empties, while the reproductive organs surround the coiled intestine, and are very large during the warmer months when the oysters are spawning.

A full-grown female oyster will produce about 9,000,000 eggs, each being about one-five-hundredth of an inch in diameter. The eggs are cast out into the water through the oviducts which open into the gill cavity on both sides of the body below the adductor muscle. They then develop into little free-swimming larvæ which swim rapidly through the water by means of their hair-like cilia. The shells then appear upon the sides of the body, and when about one-eighth of an inch wide the creature settles to the bottom with its left side down, and there remains throughout life.

The true heart of the oyster is bulb-like in shape, and lies within a delicate translucent sac close to the inner side of the great adductor muscle. It pulsates slowly, and pumps blood from the gills to other parts of the body. Growth is rapid at first, for under favorable conditions the little oyster, or "spat," as it is called, may become an inch across its shell in seven weeks, and two inches in three months.

The oysters feed upon a great variety of minute organisms, such as simple unicellular plants and animals, and small marine larvæ. The gills are covered with waving cilia, which create a

constant current providing fresh water to breathe, and also drawing into the shell the food of the oyster. The organisms serving as food are caught in the slime covering the gills, and are swept into the open mouth by the action of the cilia. Oysters are capable of detecting sound, for they close immediately when a loud noise is produced.

The Surf Clam, *(Mactra solidissima, Fig. 81).* This is also called the hen-clam. It extends from the Gulf of Mexico to Labrador, and is found on sandy beaches from low water to a depth of about sixty feet. The shell is covered with a horny, light-brown skin, and is not deeply furrowed by lines of growth. It grows to be fully six inches long and four wide. The siphon is short and thick, while the foot is large, stout and muscular, and enables the clam to dig rapidly into the sand. It does not construct a deep burrow, however, but lives quite close to the surface, and is on this account often cast ashore by storms. Its flesh is tough, and not highly esteemed as food.

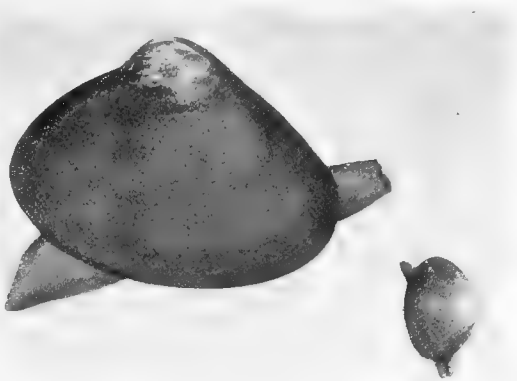

Fig. 81; SURF CLAM. From life. Young and old. Annisquam, Mass.

The Soft-Shell Clam, *(Mya arenaria, Fig. 82).* This is often called the "long clam" or "nanninose." It is found in sandy or muddy shores from the Carolinas to the Arctic, and also on the Northern coasts of Europe. It is common in the sheltered banks of bays and estuaries between tide limits, where it burrows in the ground by means of its muscular foot, having its long, extensible siphon pointing upward. When the tide is high the siphon is extended so as to reach to the opening of the burrow, but it retracts

at times of low tide. This siphon may be as much as a foot in length, and is pierced by two tubular openings, the one nearest the hinge side of the clam serving to carry off the digested food, and water from the gill chambers, while the other serves to admit water into the gill chambers of the clam. There is thus a constant current going into and passing out of the siphon. The shell is quite thin and brittle. This clam spawns in early summer, and the eggs

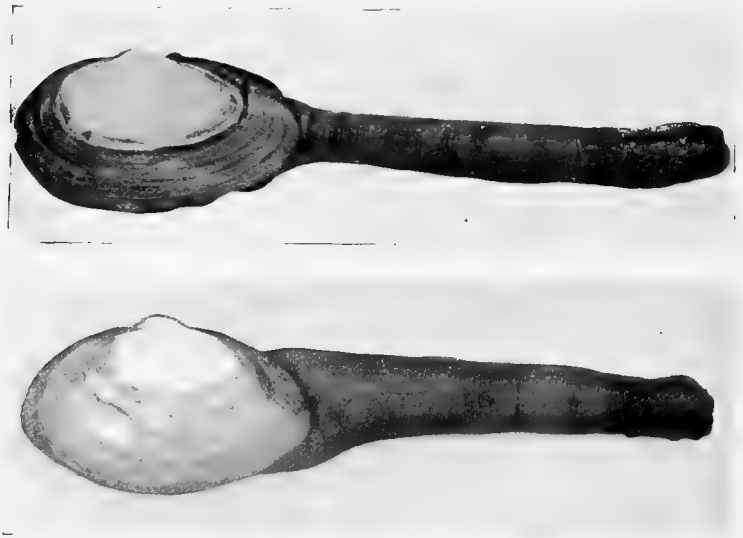

Fig. 82; SOFT-SHELL CLAM. From life. Annisquam, Mass.

develop into little free-swimming larvæ which soon settle down upon seaweed or other submerged objects and attach themselves by means of a thread called a byssus, which is secreted by a gland in the foot of the little clam. Soon they free themselves and sink to the bottom, where they begin to burrow when about one-quarter of an inch long. They still attach themselves to particles of sand, however, and often leave one burrow to construct another. Finally, however, they dig a permanent burrow which they rarely or never leave, and no longer produce a byssus.

This valuable mollusk is highly esteemed in the market. The fishery in the New England States is worth more than $500,000 annually.

The Round Clam, Quahaug, or Little-neck Clam, *(Venus mercenaria, Fig. 83)*, is the common hard-shelled clam of the New York market, and the fishery in the Middle Atlantic States is worth $200,000 annually. The Indians made their purple wampum from its shell.

The hard clam ranges from Yucatan to Nova Scotia, but is common only from the Carolinas to Cape Cod. It is most abundant in shallow bays and estuaries where it lives below the level of low tide.

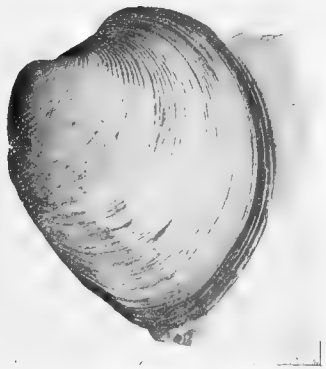

Fig. 83; LITTLE-NECK CLAM. Long Island Sound.

It is often seen lying upon the bottom, but is able to burrow to a slight depth by means of its strong muscular foot which can be protruded from the shell so as to sweep backwards and forwards over a wide area. The siphon is short and blunt, and the end displaying the two openings is forked. A continuous current of water flows in through the lower opening, and out through the opening nearest the hinge of the shell. The mantle edge around the lip of the valves is crumpled. The shell is covered by a grayish or dull brownish-gray skin, and it displays quite regular and deep rings of growth. The siphon is light yellow, while the foot is white. Kellogg finds that these clams grow very rapidly, and may become about three and a quarter times their former volume in six months. These clams feed upon diatoms and minute organisms, which are drawn into the gill chamber through the in-current tube of the siphon. The particles serving as food are collected by the slime upon the gills, and driven into the mouth by the motion of the cilia, while undesirable material is thrown upon the surface of the body or the mantle and then driven to the base of the in-current opening of the siphon, where it may be discharged by a sudden closure of the valves of the shell.

The Razor Clam, *(Ensis americana, Fig. 84)*. This curious clam resembles in shape the handle of a razor, and is found from

Labrador to the Florida Keys. The shell becomes about six inches long and is only one inch wide. The clam has a long muscular foot which can be withdrawn within the shell but may be protruded fully five inches out from the anterior end. By means of this foot the clam burrows through sandy beaches with wonderful rapidity,

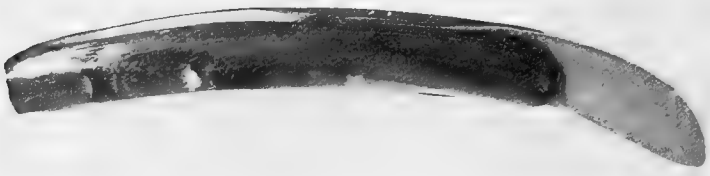

Fig. 84; RAZOR CLAM. Annisquam, Mass.

so that it is practically impossible to capture one of them with a spade after it has once buried itself beneath the surface. At low tide the clam often comes to the surface and remains with the posterior end of its shell projecting, allowing the short siphon to protrude into the air. If it be disturbed it darts rapidly back into its burrow. This clam is very palatable, but the difficulty of capturing it prevents its being sold in any quantity in the markets. It is found commonly within sandy sea beaches or sand bars where the water is not brackish.

The Sand-Bar Clam, *(Siliqua costata, Fig. 85).* This shell is about one and three-quarter inches long and three-quarters of an inch wide. It lives within loose sandy beaches and bars, in shallow water, but does not extend above low tide level. It occurs from Nova Scotia to the Carolinas but is found only in situations where the ocean water is pure. The shell is covered with a rich brown skin, which gives it a polished surface. The siphon is slender but quite long, while the foot is broad

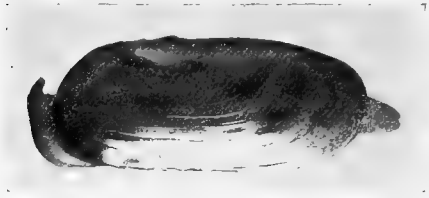

Fig. 85; SAND-BAR CLAM. Cape Ann, Mass.

and muscular and its end flattened to serve as a pushing organ. The clam burrows only a short distance beneath the sand and occasionally comes to the surface where it literally skips along by means of its powerful foot, aided by the flapping motion of its valves. In common with all other clams it feeds upon minute organisms both vegetable and animal.

The Swimming Clam, *(Solenomya velum, Fig. 86)*, ranges from North Carolina to Nova Scotia, where it burrows into sandy or muddy beaches immediately below tide level. In common with the razor clam, and sand-bar clam, it prefers pure ocean water. It is not over three-quarters of an inch in length, and the shell is thin and flexible with a rich brown surface varied by yellow lines radiating from the hinge. The foot of this clam can be expanded into an umbrella shape at its apex. When the foot is expanded and driven suddenly outward, the clam swims backward, but when the foot is suddenly withdrawn it swims forward. In this manner the clam is enabled to swim for a considerable distance through the water without touching the bottom.

Fig. 86; SWIMMING CLAM. Cape Ann, Mass.

Fig. 87; BLOODY CLAM.

The Bloody Clam, *(Argina pexata, Fig. 87)*, is common under stones or within gravelly beaches, below low-tide level, from Florida to Cape Cod. It attaches itself to stones by means of a byssus thread which is secreted by a gland in the foot. The shell is oblong, about one and one-quarter inches wide, and covered with a rough, brown skin. There are about 32 ridges that radiate outward from the beak of the shell. The gills and circulatory fluid of the clam are red. Hence the popular name of "bloody clam."

The Ship-Worm, or *Teredo, (Fig. 88)*, is not a worm but is closely related to the clams. Its peculiar elongate form and worm-like appearance are due to its habit of burrowing into any sort

of wood, excepting palmetto logs or teak. The ship-worm begins to burrow into the wood by movements of its foot and shell, when only as large as a pin's head, so that the opening to the burrow is small. For a short distance from the entrance inward the burrow is apt to be perpendicular to the surface, but it soon turns and runs more or less in the direction of the grain of the wood, although usually quite twisted. The burrow is lined with shelly material secreted by the teredo, and it is interesting to observe that no matter how numerous the teredos infesting a piece of wood, their tubes remain separate one from another and never intersect. The shelly material lining the tube is not the true shell of the teredo. The true shell is found at the head-end of the body which is farthest in from the opening to the burrow. Its two valves are small, white and delicately sculptured. The long, worm-shaped body is yellowish-white and tapers gradually to the posterior end which is near the opening of the burrow. The two long, extensible siphons are found here; and on both sides near their base are a pair of

Fig. 88; SHIP-WORM with SIPHONS PROTRUDING. From living specimens infesting wood in the New York Aquarium.

shelly flappers which serve to close the opening of the burrow when the siphons are withdrawn. A thick muscular collar at the base of the flapper also assists in closing the opening.

The teredo does not eat the wood into which it bores and is, therefore, but little affected by poisoning the timber. The most efficient protection is copper sheating. Species of teredo are widely distributed and do enormous damage to submerged timber. *Tere-*

do navalis is abundant along our shores and also on the coasts of Europe, where it has done great damage to the woodwork of the dikes of Holland.

The eggs develop within the gill cavity of the teredo and are cast out chiefly in May and June as actively swimming ciliated larvæ. They then develop a pair of relatively large shells resembling those of a clam, and finally eyes, and a long foot which enables them to crawl over timber into which they soon burrow.

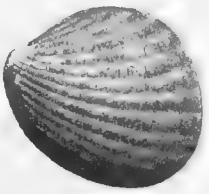

Fig. 89; COD CLAM.

The Cod Clam, *(Cardita borealis, Fig. 89)*, is one of the foods of the cod. The shell is about one inch long and three-quarters of an inch wide, and there are about 20 deep, curved, furrows which radiate outward from the beak of the shell. The shell is covered with a dark brown skin. It is common on rocky and gravelly bottoms at a depth from 30 to 600 feet from Cape Hatteras to the Arctic, and it also occurs on the Pacific shores of Alaska, and on the northern coasts of Europe.

MARINE MUSSELS

Most of the mussels, or *Mytilidæ*, are marine, although a few are found in fresh water. The shell is elongate and thin, and covered with a thick skin. The Common Edible Mussel *(Mytilus edulis Figs. 79, 90)*, abounds on mud flats between tide limits and ranges from North Carolina to California, being also common along the Arctic shores and the northern coasts of Europe. The shell is covered with a glossy black, bluish or brown skin without radiating ridges. The mussel attaches itself to objects by means of a strong yellow-colored byssus-thread which is secreted by a gland in the foot, and which soon hardens in the air into a tough, thread-like anchor rope. Great masses of mussel shells cover the shallow flats, anchored one to another by means of these threads. They can, however, leave their anchorages by casting off the threads from the foot, and then pushing themselves about so as to move into more favorable situations. They can also climb by extend-

ing the foot upwards, and attaching themselves successively higher and higher up by means of newly formed byssus threads. When the tide is high the valves of the mussels will be seen to be gaping, and the beautifully fringed edges of their mantles protruding slightly, allowing water and minute organisms to be drawn into their gill cavities, and from thence into their mouths at the opposite end of the shell. There are two adductor muscles instead of one, as in the oyster, but in most respects the anatomy of the mussel closely approaches that of the oyster. In France the mussels are cultivated and highly esteemed as food, and the fishery is worth more than $150,000 annually. We make very little use of our mussels, as at times they are said to be more or less poisonous; especially those found growing upon wood. An account of the development of the edible mussel is given by John Wilson in "Fifth Annual Report of the Fishery Board for Scotland," for 1886.

Fig. 90; EDIBLE MUSSEL. Cape Ann, Mass.

The Ribbed Mussel, *(Modiola plicatula, Fig. 91)*, can be distinguished by the radiating ridges of the shell. It is a brackish water species and is found between tide limits from Nova Scotia to Georgia.

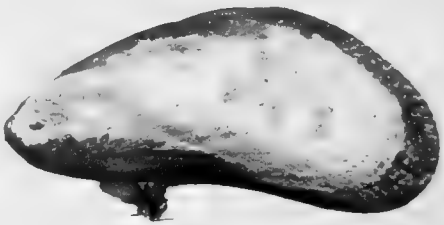

Fig. 91; RIBBED MUSSEL.

* The Horse Mussel, or Bearded Mussel, *(Modiola modiolus, Fig. 94)*, lives half buried in gravelly bottoms, or firmly attached by its byssus threads within crevices of rocks, below low-tide level. It ranges from New Jersey to the Arctic Ocean, and the northern coasts of Europe. It is chestnut brown, and the skin flakes off around the edges of the shell, forming a shaggy yellow "beard."

* An illustration of the Horse Mussel with scale limpets and egg cocoons of Rock Snail, on page 143.

Among the most interesting of the mussels are the rock boring forms called *Lithophagus, Fig. 92*, which are common in all tropical oceans. When young the shell bores into, or dissolves out, a cavity for itself within coral rocks or dead coral, and there it remains throughout life, enlarging the cavity as it grows. It is interesting to notice that some of the species of rock boring mussels attach themselves to the inside of their rocky tunnels by means of a byssus, although this can certainly serve no useful purpose, as the opening of the tunnel is always too small to allow the shell to drop out. It is evidently a habit inherited from their remote free-living ancestors.

Fig. 92; Rock-boring Mussel *(Lithophagus)* within a fragment of coral breccia. Tortugas, Florida.

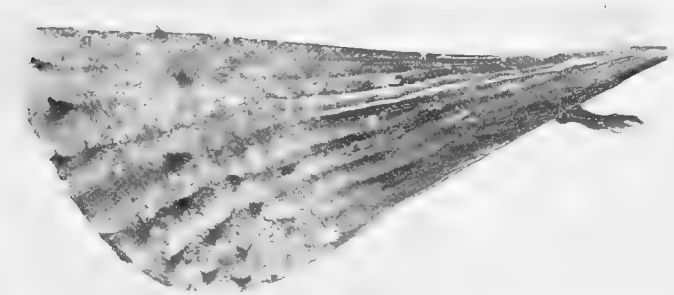

Fig. 93; RAZOR SHELL. Florida.

The author has observed a byssus formed by *Lithophagus* from the Bahamas having a shell four and one-half inches long.

The Razor Shell, *(Pinna muricata, Fig. 93)*, is another inter-

esting relative of the mussel family. It is common in shallow water along the sandy shores of the West Indies and Florida, and extends as far north as the North Carolina coast. Each valve of the shell is fan-shaped, with a sharp-pointed apex and a wide, sharp-edged margin. It attaches itself by means of a strong byssus-thread to a rock beneath the sand, and the broad edge of the shell projects above the surface of the ground. The valves of the shell open and shut rythmically, thus creating a current of water over the gills and drawing minute organisms into the ever open mouth. The razor shells, owing to their great abundance, and sharp edges, render wading with bare feet all but impossible on parts of the Florida coast.

THE FRESH-WATER MUSSELS.

There are fully 600 species of fresh-water mussels in the streams of the United States, and more than three-quarters of them live in the Mississippi and its tributaries. The shells are usually elongate and covered with a thick outer skin. The two valves of the shell are similar each to each, and there is a well developed foot, by means of which the animal ploughs along through the mud making a deep furrow with only about one-half of the posterior end of the shell projecting. There are two large openings in the mantle at the posterior end of the shell, and these openings are usually beautifully fringed. The one nearest the hinge side is the anal aperture while the other serves to admit water and minute organisms into the gill chambers. Although usually dull brown or greenish in color on the outside, the inside of the shells are beautiful, some being purple-black, others silvery white, golden copper color, salmon-pink or yellow. On this account they are highly prized for the manufacture of buttons, and this industry on the Mississippi alone is worth $40,000 annually. Valuable pearls are also obtained from these mussels.

The eggs of the fresh-water mussels are carried in pouches between the layers of the outer gills, and there they remain until they have developed a bivalve shell, the lips of which are armed with sharp, hook-like spines. The little mussel is then cast out and drops to the bottom where it comes to rest with the open valves of its shell upwards, and then it thrusts out a long, glutinous, thread

that waves through the water. If by chance this thread comes in contact with the fins or scales of a fish it instantly attaches itself, and draws up the little mussel so that it is enabled to snap its shell upon the fin and hold tightly by means of its sharp spines. This irritates the tissues of the fish, so that the skin grows over the little attached mollusk, enclosing it in a capsule or cyst. It remains thus for from two weeks to more than two months, and finally frees itself from the fish and drops to the bottom as a well developed mussel. The mussels are thus transported from stream to stream through the agency of fish, and this accounts for their very wide distribution.

Fig. 95; COMMON SCALLOP.

The fresh-water mussels of lakes and ponds are thin-shelled and belong to a group called the anodontas, while those of running streams are thick-shelled and are called unios. They grow very slowly and do not begin to breed until they are from three to seven years old, although they probably live to be from fifteen to twenty-five years of age In 1896 the pearls obtained from mussels in Arkansas were valued at $35,000, some of them being worth over $1,000 apiece

The Scallop, *(Pecten irradians, Fig. 95).* The common scallop ranges from Tampa, Florida, to Nova Scotia. It is most abundant near the eastern end of Long Island Sound, and, while common at Provincetown, Cape Cod, is exceedingly rare north of that place. It lives best in shallow bays, and harbors, where the bottom is apt to be sandy or covered with eel grass. The shell is flattened at the hinge, forming a pair of "ears," and about 19 radiating ridges extend outward from the beak of the shell. Professor Davenport found that long ago in Pliocene times the scallops had from 19 to 22 of these ridges but that the normal number for modern shells is only 19. When the scallop is young it attaches itself to eel grass, or other submerged objects, by means of a byssus composed of stout, thread-like anchorages secreted by a gland in its foot. The little

scallop thus remains attached until it is from one-half to one and a half inches long, after which it frees itself and swims actively about by flapping the valves of its shell. The mantle edge around the lips of the shell is studded with dark iridescent blue eyes which glow when alive with a beautiful fluorescence; and scattered between the eyes there are numerous delicate feelers. The large adductor muscle, that serves to close the shell, is the only part eaten by man, and is the scallop of the markets.

Fig. 96; ARCTIC SCALLOP. Maine.

The scallop breeds during the summer, and grows very rapidly, becoming more than an inch long before the winter. During the winter growth is very slow, but is resumed in the spring. It seems probable that scallops do not live to be more than three or four years old. They are captured by dredging in autumn and winter, but the supply in any one locality is uncertain, owing to the wandering habits of the animals. The scallop fishery of Connecticut and Rhode Island is worth $115,000 annually.

The Arctic Scallop, *(Pecten islandicus, Fig. 96)*, is very rare south of Cape Cod, but is quite common in depths of 150 feet and more off the northern New England coast. It ranges into the Arctic and is found on the northern coasts of Europe. The outer surface of the shell is covered with a scaly skin; there are about 100 shallow ridges, and the "ears" are unequal, the posterior one being the shorter and its angle obtuse.

The Jingle Shell, *(Anomia simplex, Fig. 97)*. This is also called the gold shell, or scale shell, and the name jingle shell is given in allusion to the ringing sound produced when the waves beat upon beaches strewn with the dead shells. The shell is scale-like and of a greenish-yellow color. It is one to three inches broad and the upper valve is convex while the lower is flat or concave, and matches the irregularities of the surface to which the shell is attached. The peculiar feature of the lower valve is a large hole near the apex. A stout, stony stalk passes through this opening,

and is fastened to the rock or other body upon which the jingle shell is growing. This stalk of attachment is in reality the byssus, and when first formed it is flexible as are the attaching threads of many other clams and mussels.

The jingle shell is found from the West Indies to Cape Cod, and is very abundant in Long Island Sound. It is, however, rare north of Massachusetts Bay, although it has been found as far north as Cape Sable. It is a shallow water form, not living at a depth greater than 70 feet.

Fig. 97; JINGLE SHELL UPON A ROCK. Long Island Sound.

The dead shells are of considerable commercial importance, for they are used by the oystermen to be strewn over the beds in order to give the little oyster a good surface upon which to set. The shell is well figured in Verrill and Smith's "Invertebrates of Vineyard Sound," p. 17 (311), Plate XXII, Figs. 241, 242, under the name of *Anomia glabra.*

The Pearl Oyster, *(Meleagrina margaritifera).* This species and several closely related varieties furnish the most valuable mother of pearl and precious pearls known. The pearl oysters are especially abundant in the Indian Ocean and tropical Pacific but they are also found in the Gulf of California, the Red Sea, and sparingly in the West Indies. The fisheries of the Persian Gulf are worth $2,000,000 annually and those of Ceylon are almost as valuable. About 15,000 tons of pearl shells are used by the world each year, the value of which ranges from about $900 to $250 per ton. The pearl oyster is a large, flat bivalve, with a long, straight hinge, and quite regularly curved contour to the shell, and is about ten inches broad. On the outside the shell is dark-olive often mottled with irregularly crescent-shaped yellowish spots, or streaked with broken yellowish lines radiating from the apex. The outer skin of the shell is rough and flakes off into long, ragged, scale-like projections, especially near the outer edges. Inside one finds the beautiful nacre of the shell

which is deposited in layers by the mantle as the shell grows. Contrary to the general opinion, pearls appear not to be formed around grains of sand but around minute parasites, or even an egg of the oyster itself. However, some foreign body causes an irritation of the mantle, and the nacre is then deposited in layers around the disturbing substance. The best pearls are spherical and are not attached to the shell itself, for if they become fastened to the shell they grow irregularly, and their value is lessened. They are always of the same color as the nacre of the shell, and as individual oysters vary considerably, this may be a steely black, a brilliant iridescent white, delicate pink or yellow. In the Gulf of California only about one oyster in a thousand contains a pearl. Pearls are most abundant in diseased oysters, or those which are attacked by boring sponges and other parasites, and are best developed in oysters about four years old. Great as may be the value of individual pearls, the pearl fisheries are mainly dependent upon the sale of the shells themselves. Immense numbers of shells are annually used in the manufacture of buttons and ornaments.

The pearl oysters attach themselves, when young, by a strong byssus-thread to rocks in water from 25 to 250 feet deep, and they are abundant in some of the lagoons of the coral islands of the Pacific in water about 100 feet in depth. In the Paumotos Islands the natives obtain them by the primitive method of diving to the bottom without the aid of diving suits or other apparatus. Having discovered the situation of a pearl shell by means of the water glass, which is merely a glass-bottomed bucket, the diver proceeds to whistle shrilly, filling his lungs repeatedly to their fullest capacity. He then jumps in feet foremost but immediately turns and swims head down to the bottom, carrying with him a half pearl shell with which to cut the living pearl shells off from the rocks below. The writer observed one experienced diver who went down in 90 feet of water and remained below two minutes and five seconds, bringing up two pearl shells. The largest known pearl belongs to Mr. Hope, of England, and has long been on exhibition in the South Kensington Museum. It is nearly four and a half inches in diameter, but is somewhat irregular. The iridescence of pearls is an optical phenomenon and is due to the interference of light caused by minute corrugations over the surface of the pearl.

SNAILS AND SLUGS.

Gasteropoda.

Fully 15,500 species of living mollusks belong to the great order of *Gasteropoda*, which means stomach foot. A wide diversity of forms are met with, but when young they all have a single shell; although this may degenerate into a mere internal scale, as in the case of the slugs, or disappear entirely in adult life as in the case of the naked mollusks *(Nudibranchiata)*.

A flat, creeping sole, or foot is usually present, and the head is distinct and usually provided with feelers and eyes, while within the mouth we find a remarkable ribbon-like tongue which is covered with rows of horny rasping teeth, and is called the *radula*.

The vital organs are contained in a large sac-like body-mass that is joined by a relatively slender neck to the upper side of the foot. In the simplest forms this body-mass is dome shaped, or conical, but in the course of evolution its weight has caused it to topple over to the left side of the body, and then in order to present the least surface to possible injury it has become coiled usually in a right-handed direction. The shell which covers the body-mass naturally has a shape similar to that of the body-mass itself, and the vast majority of gastropoda shells are right-handed spirals. This toppling over of the body-mass and shell upon the left side has caused the gill, kidney opening and other external organs of that side either to disappear or to migrate toward the right side, so that in *Gasteropoda* we usually find a feathered gill only on the right-hand side of the body, underneath the mantle-fold, although in some species the gill which was originally on the left side has come around and still persists on the right side of the body, and thus the animal has two gills on the right side and none on the left.

In the typical snail, then, the intestine bends back upon itself, and opens on the right side of the body near the head, while a little in front of the anus lies the opening of the kidney and still further forward the gill.

In a few forms we may find a kidney-duct and a gill back of the anus, these having shifted over from the left side of the body; but this condition is not often seen, for these organs have usually disappeared, instead of travelling around the body from the left to the right side.

The shell serves not only to protect the intestines, but the entire head and foot may be withdrawn within it.

In many sea-snails there is a horny or stony plate called the *operculum* which lies on the dorsal side of the posterior end of the foot, and when the foot is withdrawn this closes the opening of the shell.

The mantle projects as a curtain beyond the lip of the shell, and protects the gills and other organs which lie in the space between it and the side of the body. Often the mantle curtain is so large that it is reflected upward over the outer surface of the shell, which it may entirely encase. The secretions of the mantle serve to keep the outer surface of the shell smooth and even highly polished as in the cowries, but in many cases the shell has degenerated and become permanently covered by the mantle as in slugs.

In most of the fresh-water snails, and in land snails and slugs, the free edges of the mantle have fused with the side of the body, leaving only one opening for the admission and expulsion of air on the right side of the body.

In these forms the gill has disappeared, and a sort of lung is formed by the ramification of a network of blood vessels over the inner surface of the mantle. These snails are obliged to take in a fresh supply of air at regular intervals and if one observes a common pond snail it will be seen to come to the surface and emit a bubble of air from its air-pore and then take in fresh air before descending. Indeed, fresh water snails will soon drown if they be not allowed to come to the surface to breathe. Curiously enough practically none of these lung-breathing snails have an operculum when adult.

The gill of the operculum-bearing snails is feathered and close by the side of it one finds a smaller feathered body called the *osphradium* which is possibly an organ for tasting the water that is being breathed. In these snails one often finds opposite the gill a long tubular fold of the mantle which serves to conduct water into the gill chamber. This fold is often protected by a snout-like projection of the shell above it. The water is usually discharged through another opening which lies farther back.

The sense organs of the *Gasteropoda* are poorly developed although they are very sensitive to touch. The feelers on the head

are often not only tactile organs but serve as eye-stalks. In the land-snails and slugs the little cup-like eyes are at the extremity of the feelers while in sea-snails they lie at the base of the tentacles, or only half way up. The eggs of snails are surrounded by gelatinous envelopes or enclosed in parchment-like cocoons of definite shape. Some of the eggs of land-snails contain a great deal of nutrient jelly and may be covered with a firm, smooth shell. Indeed, they may be as large as the egg of a pigeon as in the case of our American land-snail, *Bulimus*. The early stages of segmentation in the developing eggs of snails are quite similar to those of the flat-worms, and this probably indicates that both flat-worms, and mollusks are descended from a common stock. In many of the sea-snails the larva becomes a free-swimming, pear-shaped creature propelled by one or more rings of cilia around the place of its greatest girth, and having a bristle of cilia at its blunt anterior end, and what is most interesting, the clams, mussels and ringed-worms (Annelids) go through a very similar stage in their development. Later a pair of large flat lobes grow out on either side of the mouth, and the edges of these lobes are fringed with powerful cilia which enable the little mollusk to swim rapidly through the water. The larva is now called a *veliger*. Finally the *veliger* lobes degenerate, and the shell becomes so large that the larva sinks to the bottom as a small snail.

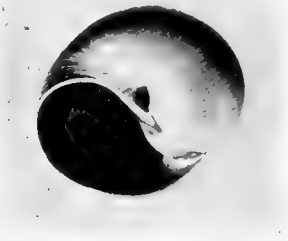

Fig. 98; NORTHERN SAND-COLLAR SNAIL. Long Island Sound.

In slugs and some land and fresh-water snails the primitive shell and operculum are sometimes cast off, and another shell which remains throughout life may develop. This casting off of the shell takes place before the little snail hatches from the egg.

A good account of the development of snails is given by Korschelt and Heider in their "Textbook of Embryology," Vol. IV, Macmillan, 1900.

The Sand-Collar Snails, *(Lunatia heros and Neverita duplicata, Figs. 98–100)*. These large snails are found in shallow water along sandy beaches, and are very abundant off the coasts of Long

Island and New Jersey. *L. heros*, *Fig. 98*, ranges from Virginia to Labrador, and *N. duplicata*, *Fig. 99*, from Yucatan to Massachusetts Bay. They may be recognized by their large size, light yellowish-brown or bluish-white color, blunt, rounded spire, and simple, round opening with a sharp-edged lip. In *L. heros* the umbillicus, or central cavity of the body whorl, is widely open whereas in *N. duplicata* it is practically closed by a plug. The whole shell is also flatter than in *L. heros*. The animal is so large that when seen expanded it seems hardly conceivable that it could withdraw into its shell. However, it can perform this feat very rapidly, and then completely close the opening with its horny operculum.

Fig. 99; SOUTHERN SAND-COLLAR SNAIL. New Jersey.

The broad, muscular foot of these snails secretes a large amount of mucous, enabling the creature to glide readily over the bottom or bury itself beneath the surface, which it always does if in danger of being stranded by the tide. The edges of the foot are sharply angular, and a large piece forward of the head is reflected back, making a thick, fleshy shield which serves as a ploughshare when the animal burrows through the sand in search of prey. The mantle is very contractible, and can be reflected upward over the shell so as to almost wholly enclose it. The surface of the shell is thus bathed in the secretion from the mantle, and kept smooth as is common with all mollusks that cover their shells in this manner. A notch-like fold in the free edge of the mantle admits water into the gill cavity. The head is provided with two sharp-pointed tentacles.

These creatures are carniverous and devour other mollusks, including the young of their own species. They are especially enemies of the clams. Applying the proboscis to the surface of the clam shell, it bores through by means of its ribbon-like tongue, which is armed with numerous rasping teeth. This boring process is usually facilitated in carnivorous mollusks by a secretion of sulphuric acid. The hole bored is circular, and its sides beveled as if countersunk.

The well-known "sand-collars" are the egg capsules of this snail. When first pressed out from the side of the animal the collar

Fig. 100; Northern Sand-collar Snail crawling over a sandy bottom between two of its egg cocoons. From life. Cape Ann, Massachusetts.

is composed of a glutinous material in which the eggs are imbedded in great numbers arranged in regular rows. Sand immediately adheres to the collar, and it soon hardens. These collars are common throughout the summer. The young snails often have two or three rows of dull purple spots running spirally down the shell; but these disappear in the adults.

The Giant Whelks, *(Fulgur carica, and Sycotypus canaliculatus, Fig. 101).* Our whelks are the largest coiled shells to be found north of Cape Hatteras. They extend from the Gulf of Mexico to Cape Cod, and are especially abundant off the New Jersey coast and in Long Island Sound upon gravelly or sandy bottoms at, or below, low-tide level, where they plough along with the foot partially buried beneath the surface of the ground. The shells of our whelks grow to be fully six inches long, and are pear-shaped, with a long, tapering snout, or anterior canal. The Knobbed Whelk, *(Fulgur carica)*, may at once be recognized by the circlet of knob-like protuberances around the shoulder of the body-whorl of the shell.

The Channelled Whelk, (*Sycotypus canaliculatus*), has no knob-like protuberances, but there is quite a deep channel at the suture of the spire. Also in the channelled whelk the shell is covered with a rough, hairy-looking skin whereas the surface of the shell of the Knobbed Whelk is smooth.

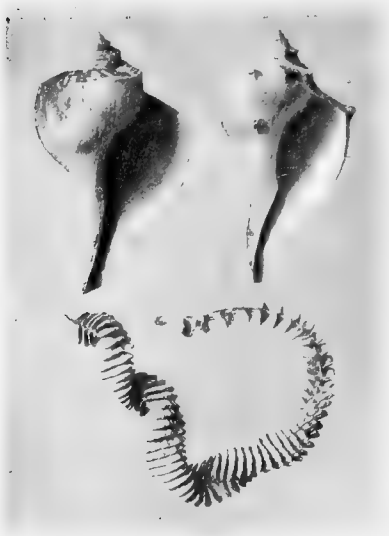

Fig. 101; Right: KNOBBED WHELK. *Left:* CHANNELLED WHELK. *Below:* Egg cocoons of the Channelled Whelk.

These animals prey upon other mollusks and are very destructive to clams and oysters. The mouth is at the extremity of a proboscis, and is armed with a ribbon-like tongue covered with rasping teeth. In eating, the end of the proboscis is applied to the victim's body, and the flesh rasped off by vigorous sweeps of the ribbon-tongue.

The egg cocoons of our whelks are often seen cast up upon the beaches, and resemble a row of yellowish colored checkers fastened upon a cord. Each checker is in reality a tough, disk-shaped capsule containing about two dozen eggs or young whelks. According to Coues, when forming the capsules the female lies buried a few inches beneath the sand and remains stationary during the process. The string of capsules is slowly thrust upward, and when completed lies exposed upon the surface. The string begins as a simple thread, without capsules, and the first few capsules are small and imperfect but soon increase in size, being most perfect at the middle of the string. There is a thin spot at the middle of the outer edge of each capsule and through this the young break their way. The capsules of the Knobbed Whelk are smooth sided disks, but their narrow edges are crossed by sharp ridges. Those of the Channelled Whelk are thinner with a thin, sharp outer edge, while the broad sides of the disks show radiating ridges.

These capsules are produced in spring and summer, but newly laid ones are also abundant in Long Island Sound during September. Formerly the Indians used these shells for the manufacture of their white wampum.

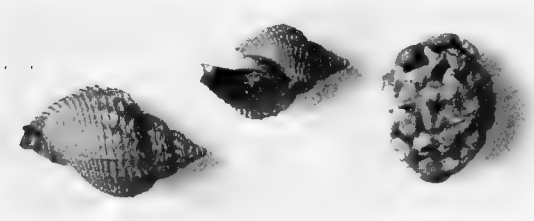

Fig. 102; English Whelk and its Egg Cocoons.

From Cape Hatteras to Cuba we find still another whelk *(Fulgur perversa)*, which resembles the Knobbed Whelk, but it is streaked longitudinally with dull, purple-brown, and its shell is coiled in a left-handed spiral.

The English Whelk, *(Buccinum undatum, Fig. 102)*, is a common sea snail in shallow water north of Cape Cod. It ranges, however, from Cape Hatteras to the Arctic Ocean, and is also found on

Fig. 94; HORSE MUSSEL, OR BEARDED MUSSEL. From life. A scale-limpet *(Patella testudinalis)*, and seven egg cocoons of the Rock Snail *(Purpura lapillus)* are seen upon the right hand shell. Cape Ann, Massachusetts.

the northern coasts of Europe. On the Maine coast it is found at low tide level, but south of Cape Cod it lives in deep water, having been taken from a depth of 3,900 feet.

The shell grows to be about three inches long, and is marked with revolving ridges and transverse furrows, and its outer surface is covered with a velvety brown skin. It is carniverous and readily feeds upon dead animals.

During the summer its egg cocoons are often found attached to rocks below low tide level. They consist of a mass of rounded

Fig. 103; Rock Snails (Purpura lapillus) devouring barnacles upon a rock at Annisquam, Mass.

capsules, yellow in color, all joined at their bases into a hemispherical mass. They are popularly and aptly termed "sea corn." Each capsule contains a number of eggs, but only a few develop, the more vigorous young devouring the weaker before hatching.

In England this snail is sold in the markets, but with us it is neglected. The lip of the shell is very apt to be broken in large specimens.

The Rock Snail, *(Purpura lapillus, Fig. 103).* This snail

literally covers the rocks on many parts of the New England coast north of Cape Cod. It is most abundant between tides, where the rocks are covered with barnacles upon which it feeds. It ranges from Montauk Point, Long Island, to the Arctic Ocean, and is abundant on the European coasts as far south as Portugal. With us it grows to be about one and one-half inches long but becomes larger on the northern coasts of Europe.

Fig. 104; TEN-RIBBED SNAIL. Massachusetts Bay.

It is very variable in form and color. Some individuals are quite smooth while others are ringed with deep ridges, or have rough, scale-covered shells. Some are dark brown, others white, gray, yellow, dull orange or ringed with combinations of these colors. The snails which live upon insolated rocks far off the coast, exposed to the full force of the ocean, are small, and are dark gray in color with dull yellowish bands. Those living on the rocks of protected shores are more variable, both in form and color.

The eggs are laid during the summer in little spindle-shaped yellow capsules which resemble minute ten pins set up on their pointed ends. They are placed on the under sides of rocks, or on dead shells. *(Fig. 94).*

A closely related species *(Purpura patula)* from the Mediterranean was used to make the Tyrian purple dye used by the Romans for their ceremonial togas. The snails were pounded in a mortar and mixed with water and soda. After a few hours the liquid changes from yellow to deep purple, and may then be used to dye wool or cloth.

The Ten-Ribbed Snail, *(Chrysodomus decemcostatus, Fig. 104)*, becomes fully three inches in length. It is yellow-brown in color, and displays ten whorled ridges. It is found off the New England

coast north of Cape Cod, and occurs just below low tide level on the Maine shore, although it is usually found in deeper water. When empty it is a favorite shell with hermit crabs, and is often dragged long distances from its true habitat.

Fig. 105; OYSTER DRILL. Long Island Sound.

The Oyster-Drill, *(Urosalpinx cinerea, Fig. 105)*, is a destructive little snail, common in shallow water on stony bottoms down to about sixty feet in depth; and while it ranges from Florida to Nova Scotia, it is rare and local north of Cape Cod.

It is most abundant in Chesapeake Bay and Long Island Sound. The shell is less than one inch long, and the lip is extended out in a projecting snout that serves to protect the siphon of the animal. It is dull brownish-gray, and there are numerous rough, raised, whorls and longitudinal ridges over the shell. The egg cocoons are laid during summer on the under surface of dead shells or stones, and are spindle-shaped, resembling little yellow vases made out of parchment. The stems of these little vases are very short, and angular ridges extend along their sides.

This snail is one of the worst enemies of small oysters and other bivalves. It rasps a small round hole through the shell by means of the sharp, horny teeth of its tongue, aided possibly by the secretion of sulphuric acid. Then having penetrated the shell it sucks the contents out at leisure. Next to the starfish there is probably no worse enemy of the oyster than this snail, and its popular name of oyster-drill is well earned. It attacks its victims throughout the year, but fortunately it is unable to drill through the shells of full grown clams and oysters.

Fig. 106; Above: NASSA TRIVITTATA. *Below:* NASSA OBSOLETA. Long Island Sound.

Large numbers of little clam shells that have been drilled by this pest are always to be seen cast up upon our beaches.

The Mud-Flat Snail, *(Nassa obsoleta, Fig. 106)*, is a small snail ranging from Tampa, Florida, to Nova Scotia. It is rare north of Cape Cod, but is most abundant on the mud flats of Long Island Sound, which it literally covers over wide areas.

The spire of the shell is blunt, and in old individuals its apex is apt to be broken off. The surface of the shell is covered with seaweed and mud, but when cleaned it is seen to be black, with a shining black interior. This snail drills holes through the shells of other mollusks and devours them. It is, however, preyed upon by young hermit crabs, that occupy the shells after devouring the mollusk itself.

Fig. 107; Periwinkles clustering upon a rock at Annisquam, Mass.

The Sand-Flat Snail, (*Nassatrivittata, Fig. 106*), can be distinguished from *Nassa obsoleta* by its sharp spire, angular suture and regularly granular surface. The shell is five-eighths of an inch long, and two sharp-pointed fleshy processes arise from the posterior end of the foot giving the impression of a pair of tails. There is a pair of long, slender tentacles on the head, and half way up on the side of each there is an eye. The siphon tube is long and curved upward, while the proboscis is even longer and extends forward as a flexible tube. The snail applies this proboscis to the surface of other snail shells, bores through by means of its rasping teeth, and then devours the soft parts of the prey. *Nassa trivittata* appears to feed upon every species of mollusk through whose shell it is capable of boring, and will readily attack individuals of its own species.

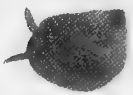

Fig. 108; PERIWINKLE. From life.

It is found from eastern Florida to Nova Scotia, and is most abundant upon sand flats in Long Island Sound, and on the Massachusetts coast north of Cape Cod. It is also found on muddy or stony bottoms and extends into water about 240 feet deep. When the tide goes out it crawls slowly over the moist sand leaving a tortu-

ous trail, and when the beach begins to dry it burrows beneath the surface head downward, but comes to rest with the aperture of the shell toward the surface.

Fig. 109; Right: PERIWINKLE. *Left:* SEAWEED SNAIL.

The Salt-Marsh Snail, *(Melampus bidentatus)*, is the most abundant snail upon the stems of salt marsh grasses near high tide mark. It ranges from Florida to Cape Cod, and is very common along the coasts of Long Island and New Jersey.

It is a little brown-colored snail of about the size and shape of a coffee berry. The aperture is narrow and elongate, the spire short and blunt, and the forward end of the shell tapers to a blunt point. Some varieties are banded with light and dark brown, while others are plain in color. This snail devours vegetable matter, and is itself preyed upon by minnows, crabs, and numerous sea birds.

The Periwinkle, *(Littorina littorea, Figs. 107–109, 111)*. This snail was probably introduced from the northern coasts of Europe or from Labrador. It is extremely abundant on the rocky shores of England, and is sold in market to the poor in large cities. After being boiled the animal is removed from the shell by a bent pin. In flavor it resembles a clam but is more delicate.

The snail was first observed on our shores at the Gulf of St. Lawrence in 1855. In 1871 it had reached the New Hampshire coast, and has slowly spread southward arriving at Salem, Massachusetts, in 1872, Woods Holl, Massachusetts, in 1875, New Haven in 1880, and at present it is found even at the western end of Long Island Sound. Wherever it has appeared it has become the most abundant sea-snail within two or three years. On the New England coast it covers the rocks and seaweed between tide limits, and Professor Bumpus gathered more than 2500 of them from a small depression in the rocks at Scaconnet near the mouth of Buzzard's Bay. The shell is thick, heavy, and dark brown, about five-eighths of an inch long, and the spire, although short, is sharp-pointed. The body-whorl is large and the outer edge of the lip is sharp and black in color while its inner (columella) side is faint purple-white. The shell is whorled with numerous shallow

furrows. It can remain out of water for hours at a time without suffering any apparent inconvenience. When the tide comes in, however, it crawls slowly about feeding upon vegetable matter. The foot is black and the head is provided with two sharp-pointed tentacles with eyes on their outer sides near their bases.

The Seaweed Snail, *(Littorina palliata, Fig. 109)*, ranges from New Jersey to Nova Scotia, and is common upon sea weeds between tide limits. The surface of the shell is smooth and is variable in color, being either olive, yellow, or brown, red or mottled, but usually closely approaching the color of the seaweed upon which it lives. The spire is blunter than in *Littorina littorea.*

The Floating Snail, *(Janthina fragilis, Fig. 110).* This beautiful snail is found floating upon the Gulf Stream, and off the Florida coast and West Indies in the spring, but it is occasionally cast up upon our shore by southerly gales. The shell is blunt and about one and a half inches in width, and is of a beautiful purple-blue color, lighter over the spire than at the base of the body whorl. It is almost as thin as paper, and is usually broken by the surf in being washed ashore. A gelatinous substance is secreted by a gland in the foot of the animal, and this becomes filled with air bubbles and hardens to form a veritable raft that floats the snail. The female even deposits her eggs in spindle-like capsules on the under side of this raft, the youngest eggs being nearest the body of the snail, and the oldest on the outer end of the raft. The feathery gills project beyond the lip of the shell, and there are four tentacles upon the head. While the float remains attached it is impossible for the snail to sink, but it may apparently be cast off at will. When pressed the snail exudes a blue-violet fluid.

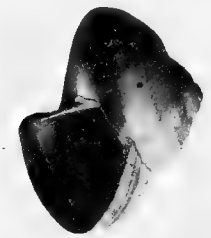

Fig 110; FLOATING SNAIL. Tortugas, Florida.

The Boat Shells, *(Crepidula).* These are often called "deckers" or "slipper limpets." They are degenerate, scale-like snails, and when full grown either remain fastened permanently to one spot or move very slowly. Those species that become fast to one

spot fit closely over the stone or dead shell to which they are attached, the attachment being made very secure by a stony cement that is secreted by the foot. The eggs are laid in round capsules which are attached to a minute cord in grape-like clusters. Each little capsule contains a large number of eggs floating in a nutrient jelly. From two to twenty thousand eggs are laid, and are fastened to the ground by the side of the animal so as to be covered by the shell itself. The breeding season extends from early summer until about August 15th. Our species range from the West Indies to Nova Scotia, and are very common in Long Island Sound.

Fig. 111; Eel Grass, at low tide, covered with Periwinkles. Annisquam, Mass.

Crepidula fornicata (Fig. 112), the largest species, is found attached to horse-shoe crabs, and also to stones and dead shells. A succession of individuals being often seen fastened one to the shell of the other with the last shell in the line fastened to a stone or

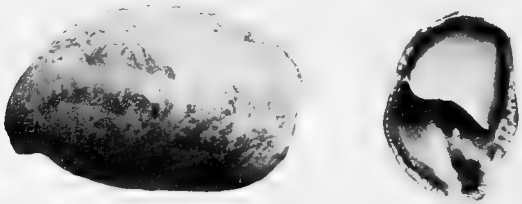

Fig. 112; DEC'KER SHELL. Long Island Sound.

other firm anchorage. In these strings of shells the heads are usually pointed all in the same direction. The young hatch as

free-swimming veliger larvæ, but after two or three weeks they settle down as young boat-shells. Until they are about half grown they can move slowly, but finally they become fixed for the remainder of their lives. The males are smaller and more active than the females, but they also lose all power of locomotion when more than half grown. This species may be recognized by its decidedly convex shell, gray, horny color, and faint reddish-brown flecks over the surface of the shell.

Crepidula plana is a small, flat, white species which lives within shells that are being carried about by hermit crabs. The head end of the crepidula almost always faces the opening of the shell within which it lives. Its breeding habits are similar to those of *C. fornicata.*

Crepidula convexa is the smallest of our species, and its shells are dark brown in color, and more convex than either of the others. It lives on the outside of shells, being carried about by hermit crabs. It can move to a limited extent throughout life, and the young hatch as little snails, and do not pass through a free-swimming veliger stage.

A most thorough account of the development and life history of our species of *Crepidula* is given by E. G. Conklin in the "American Journal of Morphology," Vol. XIII, Part 1, 1897.

THE NAKED MOLLUSKS OR SEA SLUGS.

Nudibranchiata.

These are slug-like in general appearance but are not to be confused with land slugs. They have a flat creeping foot, and no shell when adult, although one is present in the young, indicating that they have descended from sea snails. However, the shell and operculum which are found in the young larvæ are cast off very early in development.

The mouth is on the lower side of the front end of the body, and the intestine usually gives off branched canals which ramify through the body. The vent is either upon the middle line of the back or upon the right side. When found upon the mid-dorsal line it is usually surrounded by branching gills which are often highly colored and resemble a beautiful flower. These gills are,

however, not derived from the plumed gills of other snails, but are a new formation found only among the *Nudibranchiata*. The back is apt to be covered with finger-shaped processes which probably function in respiration, and the head is provided with eyes and tentacles.

These most interesting little snails match their surroundings to a wonderful degree of perfection, their ragged-looking backs and mottled color giving the impression of a piece of torn seaweed. They crawl upon sea weeds or stones, but can also swim foot upwards along the surface of the sea.

Æolis papillosa is the commonest species under stones or upon sea weeds in shallow water off our north Atlantic coast, and the shores of Europe. It grows to be about three inches long, but specimens over an inch in length are rare. It is very variable in color, being fawn, gray, or yellowish sprinkled with large dots of white, olive, brown, purple or yellow. The body is square in front but tapers to a point behind. There are two pairs of tentacles upon the head, and numerous rows of papillæ, down both sides, the middle of the back being bare. The eggs are laid in a white gelatinous cord, festooned and coiled in a spiral, and deposited upon stones. A good figure and description of this creature is given by Gould and Binney. "Invertebrates of Massachusetts," p. 238. Plate XVIII. Figs. 257–263. Curiously enough the skin of this creature is provided with stinging thread-cells similar to those of jelly-fishes and sea anemones. It is probable, however, that these thread cells may have been obtained from sea anemones upon which the mollusk has fed.

Ancula sulphurea is a pale yellow species commonly found on rocky bottoms off the New England coast north of Cape Cod; being very abundant in water about 200 feet deep.

THE SQUID, OCTOPUS AND NAUTILUS.

Cephalopoda.

These are the most highly developed mollusks, and when one observes their remarkably rapid movements, their acute senses, and the complexity of their entire organization, it is difficult to convince one's self that their nearest living relatives are snails and clams.

They are all carniverous, and prey upon fishes, crustacea and other mollusks which they capture by darting backward, seizing

the victims in their sucker-bearing arms, and crushing the prey in their sharp, parrot-like beaks.

Nothing in nature is more gruesome and hideous than the sinuous writhing of these creatures, or more strangely fascinating than the wonderful play of varied colors over their soft, pulsating bodies, this movement contrasted all the time with the cruel, stony stare of their expressionless eyes.

The octopus often takes up its abode within some rocky crevice, and lies safely hidden in the shadow, at the same time similating the color of its surroundings so that its victims do not perceive

Fig. 113; OCTOPUS AMERICANUS. From a painting made at Tortugas, Fla., by Herbert B. Judy.

their danger until grasped by the suckers of the long, muscular arms. This habit of seeking caverns is well known to the Japanese, who capture the octopus for the market by simply sinking earthenware urns over night, and then drawing them up in the morning, when some of them are found to be occupied by these repulsive creatures.

Despite their generally musky odor octopi and squids are eaten

in France, Italy and Japan. They are also preyed upon by sea lions and sperm whales.

In the octopi there are eight, and in the squids and sepia ten long, flexible arms that surround the mouth, and in many species the rims of the suckers are beset with hooks, thus increasing the tenaciousness of their grasp. A careful study has shown that these arms are derived from what was once the fore part of the foot in the ancestral mollusk, from which the *Cephalopoda* are descended. The mouth is provided with a pair of powerful, parrot-like beaks, while the tongue is beset with sharp, rasping teeth. In all forms the teeth and jaws are horny, but in Nautilus the beaks are coated externally with calcareous matter.

The chambered nautilus of the tropical Pacific and Indian Ocean is the only living species whose shell is wholly external. This graceful shell is composed of a series of chambers filled with gas, and coiled in the form of a regular spiral. These chambers are separated one from another by shelly partitions, but each partition is pierced at its centre to allow of the passage of a tube called the siphuncle, which runs through the compartments, and is attached to the back of the body of the nautilus. The animal itself lives in the largest and last formed chamber, into which it can almost completely withdraw its head and tentacles.

The *spirula* of the tropical Atlantic and Pacific has also a chambered cell, but this is largely covered by the mantle, and is small in comparison with the size of the animal, and curiously enough the shell of spirula is coiled in a manner opposite to that of nautilus. These graceful cream-colored little spirals are found cast up upon the sands of every coral island, but the living animal is exceedingly rare, and almost nothing is known concerning its habits.

In the squids the shell is also internal and imbedded in the mantle, and is reduced to a mere remnant popularly called the "pen," in allusion to its peculiar shape, while in the octopus the shell has disappeared entirely in the adult animal.

The so-called shell of the paper nautilus or *Argonauta* is not to be compared with the shell of other mollusks, for it is merely a shell-shaped capsule secreted by broad, flat expansions of two of the arms. Its resemblance to a shell is merely accidental, and it serves

only as a pouch to contain the eggs while they are being carried about by the female. When first taken from the water it is soft and flexible, but soon hardens and becomes very brittle in the air. When much disturbed the female may cast it off, and it is never developed by the male argonaut.

In all forms excepting the chambered nautilus the body is cone-shaped or dome-like, and is enclosed in a mantle which is attached along the back, and hangs freely around the body, encasing it as a bag on the sides. The head and tentacles project beyond the mouth of the mantle-bag, as does also the siphon. This siphon is a tube which is developed on the side of the head, and is open at both ends. In the adult nautilus and in all embryonic Cephalopods this siphon is composed of two side flaps whose edges fold together to form a tube, but in all adult cephalopods, excepting nautilus, the edges fuse forming a solid-walled tube.

When the mantle-bag expands, water is drawn in through the slit between the body and mantle on both sides of the neck. If the animal be quietly breathing, the water is forced out through the same slit by the contraction of the mantle, but if the cephalopod desires to move, the free edge of the mantle-bag becomes hooked to the outer wall of the siphon, thus closing the neck-slit so that the water is driven forcibly out through the tube of the siphon. This siphon tube usually projects forward, and the concentrated stream of water rushing out of it forces the animal backward with great rapidity. The siphon can, however, at times be directed backward, thus driving the animal forward, but this is so rarely done that it can not be called the usual manner of progression.

A careful study of the subject has convinced naturalists that the siphon has been derived from what was the middle part of the foot, in the extinct mollusks from which the Cephalopods have descended.

The so-called "side fins" and "tail" of the squid are mere expansions of the mantle. It is interesting to observe that the so-called tail fin is not at the posterior end of the body but at the highest point of the back of the animal. The sucker bearing arms being derived from the fore part, and the siphon from the middle part of the foot, while the conical body has been elongated dorsalwards. These things can, however, only be fully comprehended

through careful study, and the only point we should remember is that it is not quite correct to say that the squid "swims backward" but that it swims with the middle point of its back directed forward.

Feathered gills arise from the body, and project into the cavity of the mantle-bag, so that they are bathed by the water that comes in through the slit-like opening between the mantle and the sides of the neck. In nautilus there are four, whereas in all other cephalopods there are only two gills. In common with other mollusks the heart pumps blood from the gills to other parts of the body.

The kidneys, genital organs, and alimentary tract also open into the cavity of the mantle-bag and their products are discharged with the waste water through the siphon.

The ink bag is a peculiar organ that is found in all forms excepting nautilus. Its duct opens into the intestine near the vent, and when the animal becomes excited or alarmed the inky fluid is discharged through the siphon thus darkening the water and enabling the animal to bewilder its prey, or to itself escape from danger. Both india ink and sepia are made from the fluid of the ink bags of cuttle fishes.

The nervous system is far better developed than in snails and other mollusks. The brain is large and is protected by a sheath of cartilage, while the eyes bear a close but only accidental resemblance to those of vertebrates. In nautilus, however, the eye is a mere cup-shaped cavity, the bottom and sides of the cup being lined with sensory cells constituting the retina; but in all other cephalopods the eye is much more complex. On the outside we see the glassy cornea or window of the eye, and close behind it lies the iris with its circular or slit-like aperture of the pupil. The lens is large and spherical and lies back of the iris, almost filling the cup-like cavity of the eye which is elsewhere filled with a transparent fluid. The retina lining the cavity of the eye is not turned inside out as in the case of vertebrates, but receives the light directly. There are two ear-like organs on the side of the head, which enable the animal not only to hear, but also to maintain its equilibrium in the water.

The wonderful color changes of the Cephalopods have caused them to be described as "chameleons of the sea." Immediately under the skin there are large numbers of little pigment cells with muscular walls. When the walls contract each pigment cell is re-

duced to a mere dot and is practically invisible, but when the walls expand the cell enlarges to fully twenty-five times its former area, and the sudden enlargement of thousands of these little pigment cells, or chromatophores, as they are called, produces a flash of color. There are several sets of these chromatophores, some rosin colored, others yellow, blue-green or brown. Each set may expand independently or in combination with the others and thus a varied play of color is produced.

In Cephalopods the sexes are separate, the male being often much smaller than the female. In some forms, such as the paper nautilus, one of the arms of the male undergoes a curious transformation. It develops within a large sac which bursts leaving a part of the sides of the sac still attached to the arm. The male then places a packet of *spermatoza* upon the arm, and after seizing the female the arm breaks off, and becomes attached to her body within the mantle cavity, thus conveying the *spermatoza* for the fertilization of the eggs. The eggs are usually laid enclosed in gelatinous capsules and the development is direct without any free swimming larval stage such as is characteristic of other mollusks.

Fig. 114; THE CHAMBERED, OR PEARLY NAUTILUS. From the Tropical Pacific.

A good general account of Cephalopods is given by Professor J. S. Kingsley in the "Riverside Natural History," Vol. I.

The Chambered Nautilus, *(Nautilus pompilius, Fig. 114).* This most interesting creature is found in the western parts of the tropical Pacific, and in the Indian Ocean. It lives upon the bottom, and is not usually found in water less than 100 feet deep, being most abundant at a depth of about 1000 feet. Contrary to popular

belief it never swims at the surface. The chambers of the shell, the construction of which we have already mentioned, are filled with gas, this being a mixture of oxygen and nitrogen resembling ordinary air, but being richer in nitrogen. This gas probably serves to increase the buoyancy of the shell, so as to enable the animal to move more rapidly. The animal itself is confined to the outermost and largest chamber of the shell. The mouth is provided with a pair of parrot-like beaks composed of a black, horny substance, coated on the outside with shelly matter. There are about 90 tentacles around the mouth. These have poorly developed suckers, and can be retracted each into its own special sheath. The sheaths of two of these tentacles are fused into a broad, flat plate called the hood, that serves to partially close the aperture of the shell when the animal retracts. This hood lies on the back of the head, while on the lower side we find a tube made of two side folds which overlap. This is the "siphon" or funnel through which water is expelled, driving the animal backward. In this manner it swims through the water near the bottom, gliding along with the aperture of the shell turned upwards and the tentacles held close together and trailing out horizontally. The writer was informed by natives of the Paumotu Islands, however, that the nautilus also crawls over the bottom, and often buries itself beneath the sand.

In the Philippine Islands the nautilus is captured in traps somewhat similar in construction to our lobster-pots, the bait used being pieces of chicken or even dead dogs and cats. The animal is eaten in these islands but is not highly esteemed, and a better price is now obtained for the shell, which is used in China for the manufacture of pearl buttons.

The tentacles and funnel-tube are opaque-white, while the hood is speckled with brown and yellow spots. There is a simple, pit-like eye mounted on a short stalk on either side of the head, and this is so placed that it can obtain a view of the surroundings even when the creature is almost completely retracted, and the aperture of the shell all but closed by the hood. The shell of the nautilus is smooth and white and marked with bands of reddish-brown, while the inner side of the aperture is marked with jet-black where the mantle fold is applied to the shell. The partitions of the cham-

bers and the whole interior of the shell are lined with pearly nacre, having a lustre only slighty inferior to that of the pearl oyster.

The nautilus is one of the most interesting of living animals, for it is the sole survivor of a once numerous race, great numbers of which swam in the ocean during Silurian times. The oldest forms are apt to have straight shells, but later we find them for the most part coiled, while during the last ages of their decline they sometimes uncoiled to a greater or less degree, or assumed strange contorted shapes. Some were five or six feet in length, and one species must have weighed several tons.

Associated with the nautilus race was another great group called the *Ammonites* in which the margins of the partitions separating the chambers of the shell were complexly folded. Their shells were also highly ornamented with ridges and projections and the siphuncle was small and did not usually pass through the centre of the partitions, but ran through the edges close to the wall of the shell. More than 5000 species of *Ammonites* and 2500 of the nautilus race lived in these ancient times. The *Ammonites* died out completely in the age of the chalk, while the nautilus race declined slowly, until to-day we find its last representatives still living in the depths of the tropical Pacific. Three or four species of Nautilus are found in the tropical Pacific, the best known being *Nautilus pompilius*.

THE SQUIDS, OR SEA-ARROWS.

Several species of squids occur along our coast. Their bodies are spindle-shaped, tapering to a point behind, while the fin resembles in outline an arrow or spear-head. The shell is degenerate, and is reduced to a mere internal scale imbedded in the mantle and called the "pen" in allusion to its shape. Ten arms surround the mouth. Eight of these are triangular in cross section, and are each furnished with two rows of suckers on their inner sides. The fourth pair of arms are, however, much longer than the others, and have suckers only upon their expanded tips where we find four rows of these organs of adhesion. The eyes are large, have no lids, and the pupil is a round opening.

Squids usually swim backward, being propelled in a series of rapid darts by the water which is sucked in through the mantle-

slit on the sides of the neck, and discharged through the siphon which projects outward from the mantle-cavity under the head. Occasionally, however, the siphon is turned backward, thus caus-

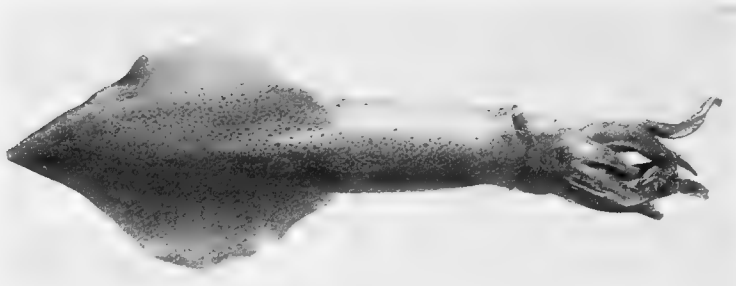

Fig. 115; BLUNT-TAILED SQUID. New Jersey Coast.

ing the animal to dart forward, but this method of progression is rare in comparison with the backward darting. They can also swim slowly forward when propelled by movements of the fin. Squids feed upon small fishes, crustacea, and even the young of their own species, and they are themselves devoured by numerous fishes, the sperm whale and seals. In killing a small fish they bite a piece out of the back of the neck. They capture their prey by darting rapidly backward, swinging quickly to one side and seizing the victim in their sucker-bearing arms.

Very commonly they become stranded in their backward darting flight, and then thrash helplessly upon the shore, forcing water out through the siphon and ejecting their jet-black ink. The shores of Maine are often strewn with squids that have perished in this manner, this being especially noticeable after moonlight nights. Indeed, the fishermen take advantage of the attraction squids display for light by placing a beacon in the bow of their boats and slowly rowing ashore, thus stranding the congregated animals.

They often swim in schools, especially during spring and early summer. During some years the water fairly teems with them, and then again none will be seen for long periods of time. As they dart through the ocean their color changes instantly to match their

surroundings, while at times flushes of steely-blue, purple, reddish or yellow flash over the body as the creature swims.

These changes of color are produced by the contraction and expansion of several sets of pigment cells beneath the skin. For example,—when the reddish-brown set contracts, the brown color is so reduced that it almost disappears, whereas the expansion of these pigment cells instantly tinges the whole surface.

Although these creatures are but rarely sold in market, their flesh being little esteemed as food, more than 1,000,000 pounds of squids valued at about $14,500 are taken annually upon the Massachusetts coast, to be used in the cod fishery, and about one-half of the bait used upon the banks of Newfoundland consists of squids.

Squids lay their eggs upon weedy bottoms throughout the summer, the eggs being contained in clusters of gelatinous finger-shaped capsules, each capsule holding a large number. These clusters are often five or six inches in diameter and are known to the fishermen as "sea-grapes."

The Blunt-Tailed Squid, *(Loligo pealii, Fig 115).* This is the common squid from the Carolinas to Cape Cod. North of this point it is rare, and it does not extend beyond Cape Ann, Massachusetts. It becomes about a foot in length, and is usually speckled with rusty-brown or purplish color, although its color constantly changes in intensity. The fin is large, obtusely rounded on the outer edges, and about as broad as it is long. A closely allied pale translucent variety called *Loligo pealii* var. *pallida* is most abundant in Long Island Sound.

The Short-Tailed Squid, *(Ommastrephes illecebrosus).* This is the common squid of the New England coast north of Cape Cod, and is most extensively used as bait in the cod fishery. The fin is one-third broader than it is long, and its outer edges form nearly a right angle.

The Giant Squid, *(Architeuthis princeps, Fig. 116).* This is the largest living invertebrate, and the sudden appearance of its writhing arms upon the ocean has probably given rise to stories of the sea serpent. It has been seen but rarely, and then always upon the Grand Banks or off the coast of Newfoundland. Altogether not more than thirty specimens have been found, and the majority of these were badly damaged. The arms are as thick as a

man's leg and their suckers as large as tea-cups. One obtained in 1877 had a body nine and a half feet long and seven feet in

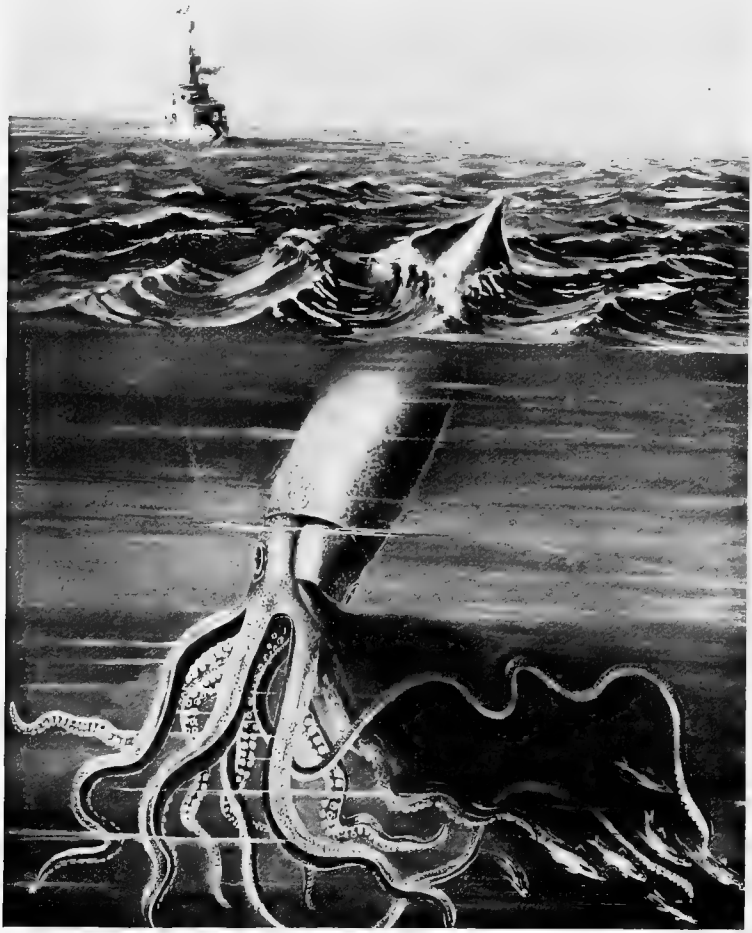

Fig. 116; GIANT SQUID of the Newfoundland Banks. From a painting by Herbert B. Judy.

girth, the arms being thirty feet long. It was exhibited at the old New York Aquarium and afterwards in other places, but unfor-

tunately it is now lost. The largest ever seen was stranded—while yet alive—on the coast of Newfoundland, and was cut up for dog meat by the fishermen who captured it. Its body was said to have been twenty feet and the tentacles thirty-five feet in length. The fabulous *Kraken* of the Norsemen was probably a giant squid. In their old sea-tales we read of its devouring ships, and indeed it is well established that large squids have at times attacked fishermen's boats.

In every respect, excepting size, these monsters resemble the little short-tailed squid of the New England coast. Nothing is known of the habits of the giant squid, although it probably lives in deep water off the Banks and only occasionally comes to the surface at night. Powerful as these monsters are, they are greedily devoured by the sperm whale.

The American Devil-Fish, *(Octopus americanus, Fig. 113).* This creature is found upon the coral reefs of Florida and the West Indies, where it lives within rocky crevices, the color of which it exactly matches. Here it lies in wait for prey, and the floor and entrance of its den are strewn with the broken shells of mollusks and crustacea that have fallen victims to the Octopus. It also glides ghost-like over the sands, resembling the glistening white bottom so completely that it is all but invisible. This gliding movement is accomplished by opening and closing the umbrella-like web that forms a span between the bases of the arms. At every such pulsation the creature shoots backward, trailing its eight long arms, which extend straight outward. The creature can also accomplish the same movement, or a side motion, by expelling the water from its siphon tube, which usually projects out to one side from the edge of the mantle. If grasped the writhing arms, with their double rows of suckers, instantly seize upon the tormentor, and the sharp, parrot-like beak inflicts a painful wound. Ink is also ejected from the siphon, and a wonderful play of colors pass over the body, flashing steely blue, green, brilliant white, rusty red or dull brown. When removed from the water the creature thrashes about in hideous contortions for a few minutes and then dies utterly exhausted. The eyes are frog-like and prominent, with a slit-shaped pupil, and the skin around them can be drawn together from all sides, forming a veritable eye-lid. The body is soft and rounded and there

are no fins, and no trace of a shell in the adult. When full grown the arms are each about two feet long. In the male the third arm on the right hand side is curiously modified for sexual purposes, and is cast off and adheres to the female during the breeding season.

Another species of Octopus, *(O. bairdii)* is found in deep water off the New England coast, but it is not often met with. A good figure of it taken from Verill is given in the "Riverside Natural History," Vol. I, p. 371.

The Paper Nautilus, *(Argonauta, Fig. 117).* Several closely related species of *Argonauta* are found in the tropical parts of the Atlantic and Pacific Oceans. Occasionally the creature is drifted northward upon the Gulf Stream, and may be cast up upon the southern Long Island coast. The female has eight sucker-bearing arms, which resemble those of the Octopus, excepting that the front pair of arms end each in a large, flat expansion. These expanded parts secrete a delicate capsule which bears an accidental resemblance to a beautifully-sculptured shell, although it is not comparable with the shell of other mollusks. It is not attached to the body, and may be even cast off, and serves merely to contain the eggs during the breeding season. These eggs are laid in grape-like clusters enclosed in delicate capsules. The six tapering arms may also be thrust within the cavity of the capsule while the Argonaut swims backward, being propelled by jets of water from the siphon.

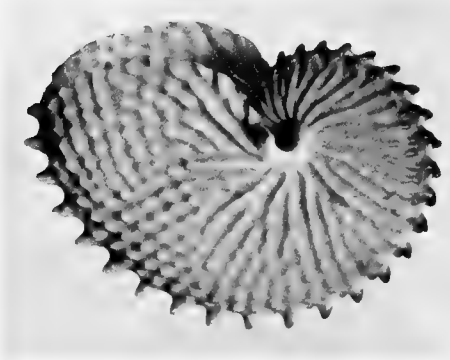

Fig. 117; PAPER NAUTILUS. From the Tropical Pacific.

During the breeding season the females are found swimming at the surface, but at other times they appear to live in the depths. Beautiful colors play over the creature as it swims about, and the shell, while in the water, is very soft and flexible.

The male Argonaut is only about one-tenth as large as the female, being about one inch in length. Previous to the breeding season the third arm on the left side is seen to be developing inside of a sac. Later this sac splits along on one side and turns inside out, thus freeing the arm, which is then seen to be more than twice as long as the ordinary arms of the animal, and to terminate in a long pointed filament which was itself developed in a sack very much as was the base of the arm. A number of long filamentous tubes containing *spermatozoa* are placed within the cavity of the sac at the base of the arm. At the breeding time the entire arm is cast off, enters the mantle cavity of the female, and adheres to her body. The male Argonaut never develops a shell.

It is in the contemplation of creatures such as this that we come to realize the hopelessness of any attempt to measure by our puny standards the immensity of time that has elapsed since evolution began to mold the manifold forms of life. How long may it have been before such a remarkable contrivance as the shell-like brood-pouch and such a curiously modified arm as that of the male Argonaut could have been developed?

Altogether there is no more comprehensive picture of the course of evolution than that furnished by the fossil shells of Cephalopods. We see the straight-shelled Nautilus race that swarmed in the ancient Silurian seas, when the whole western half of New York State was submerged by an ocean continuous with what is now the Pacific. Afterwards in Devonian times we find the sculptured Ammonites appearing in a vast variety of forms. Then the Nautilus race slowly faded away until to-day we find its last lingering descendant living in the depths of the Pacific, while the Ammonites, their shells coiling and uncoiling in writhing, snake-like shapes, died out forever, while the Chalk cliffs of England were yet beneath the sea.

Only the soft bodied squids and octopi which first appear in Triassic seas, still survive in reduced numbers in the oceans of to-day.

THE SEA-SQUIRTS,

Tunicates or Ascidians.

ATTACHED to rocks, sea weeds or piles of wharves, one sometimes finds a globular or dome-like mass of tough, gelatinous consistency, usually dull in color, and often covered with sand or detritus. If the creature be touched it contracts, and a fine stream of water is forced out of two openings that will be observed quite close together near the highest point of the dome-like body This habit has led to their being commonly designated as "sea-squirts." The older naturalists were inclined to believe that they were related to mollusks, but a study of their development showed conclusively that they are lowly organized and degenerate vertebrate-like animals in which a flexible rod serves as a back-bone, although it must be remembered that this rod is tough and gelatinous in consistency—not bony. It is interesting to observe, however, that the central part of the backbone of all vertebrates, from the lowest fishes up to man, is at one time a flexible rod exactly similar in origin and constitution to that of the tunicates. In higher forms, however, this primitive rod becomes surrounded, and often all but obliterated by a casing of cartilage or bone, thus greatly increasing its efficiency as a support for the skeleton and muscles.

But to return to the tunicates; no one would have supposed that these unattractive, almost shapeless creatures were primitive vertebrates until their development was studied, and it was discovered that the larva is free-swimming and resembles a tadpole in hav- a large head and long, lash-like tail. Moreover, we find that extending a short distance down the middle of the back immediately under the skin there is a nervous tube in every way comparable with the spinal cord of vertebrates, while parallel with, and lying under this tube we find a flexible, rod-like structure that is evidently similar to the central core of the back bone of all vertebrates.

The head of the tunicate embryo is also interesting, for we find on the dorsal side a single eye, and in front of this a primitive

ear-like organ; and the remarkable fact is that the retina and lens of the eye and the sensory part of the "ear" are derived from the walls of the brain as is the case in vertebrates.

After swimming about for some time the tunicate tadpole usually settles down upon the bottom and fastens itself to a situation from which it never departs. Under these conditions it finds almost no need for sense organs or skeleton, and accordingly these degenerate to such a degree that the eye disappears completely, and the other structures are reduced to mere remnants.

But all tunicates do not thus settle down and degenerate, for some of them remain active throughout life, swimming rapidly through the water. One of these free forms called *Appendicularia* remains tadpole-like in shape throughout its existence, having a pair of gill-slits, one on each side, and a long powerful tail which is provided with a fin, and arises from the middle of the ventral side of the body.

Many tunicates are solitary animals while others produce large colonies by budding, the older members of the colony giving rise to the younger. In other forms such as Salpa, there is an alternation of generations, one being produced from eggs and the following generation through budding.

A tunicate has been aptly compared to a leather bottle with two spouts. The outer covering of the body is usually tough in consistency and contains cellulose, the composition of which is identical with the substance that forms the walls of plant cells.

A moment's observation of the two funnel-shaped spouts will show that water is constantly being drawn into one and forced out from the other, and a further study shows that the water is drawn in at the spout at the front end of the body, and passed out of the opening upon the back of the animal. The intestine is U-shaped, and the mouth is at the place where the water enters while the vent is at the spout through which the water passes out.

The throat is a wide sac almost as long as the body itself, and is pierced by so many little gill slits that its sides resemble a sieve. The water enters the mouth, passes through these gill slits, and finally out through the dorsal spout; the current being maintained by the beating in unison of thousands of hair-like *cilia* which line the gill slits.

The minute animal and vegetable organisms that are drawn in with the water do not pass through the gill slits, but are caught in the slime that lines the throat and passed around, entangled in a cord of slime, into the stomach.

The heart is a spindle-shaped tube lying under and near the stomach. Curiously enough it pumps blood in one direction for a few moments, then rests, and pumps in the opposite direction. The blood corpuscles are mainly colorless and constantly change their shape resembling *amoebæ*. Some of the blood corpuscles are, however, of definite shape and are often deeply colored, being reddish, indigo, brown or even white. It has been found that when *bacteria* or other disease germs are introduced into the blood system, the colorless blood corpuscles seize upon them, and attempt to engulf them. Sometimes, however, they do not succeed but are themselves destroyed in the attempt to digest the bacteria, and then the disease conquers in the strife.

Fig. 118; CIONA INTESTINALIS. From Woods Holl, Mass.

The genital organs are found close to the side of a loop of the intestine, and their duct opens at the dorsal spout. In common with many sedentary and degenerate animals all tunicates are hermaphrodites, but the same individual does not usually fertilize its own eggs.

The "brain" or principal ganglion of the Tunicate is situated midway between the two spouts, and is simply the remnant of the larval brain. It is, however, of so little importance that if it be cut out the creature lives quite well, and is even capable of contracting in a normal manner when touched. The "brainless" animal

is, however, less sensitive, and its reactions are slower than in the normal creature.

A good account of Tunicates, their development and relationships, is given by Arthur Willey in "Amphioxus and the Ancestry of the Vertebrates," 1894, and also by J. S. Kingsley in "The Riverside Natural History," Vol. III. Most valuable general treatises upon the subject are also given by W. Herdman in "Report on the Tunicata," in the Reports of the Voyage of H. M. S. "Challenger," Zoology, Vol. VI.; and by W. K. Brooks in "Salpa," Memoirs Johns Hopkins University Laboratory, 1893. A valuable summary for higher students is given by W. A. Herdman in The Cambridge Natural History, Vol. VII., pp. 33–138, Macmillan & Co., 1904.

Ciona intestinalis (Fig. 118). This large sea-squirt is found upon our shores, and is also abundant in the Mediterranean and on the coast of England. It is found upon the under sides of stones or upon the shady sides of wharf piles immediately below low tide level.

It grows to be four inches long and the body is slender, and is of the shape of an urn with two spouts, one at the narrow end and one at a short distance below the terminal opening. The terminal opening is at the forward end of the animal, and serves as a mouth for the admission of water and food; while the lower aperture arises from the back of the creature and serves to carry off the water which has passed through the numerous gill slits of the huge throat, and to conduct away the waste products of the body.

The animal is dull yellowish or greenish in color, and the apertures are bordered with brilliant greenish-yellow. The body is translucent, and there are from twelve to fourteen powerful strands of longitudinal muscle fibres which appear as opaque glistening lines. If the animal be disturbed these longitudinal muscles contract rapidly, so that the creature shrinks into a shape even broader than long.

In common with all tunicates this creature is hermaphroditic but is practically incapable of fertilizing its own eggs. These are discharged with clock-like regularity at one and one-half hours before sunrise by means of a series of violent contractions, and are fertilized in the water by *spermatozoa* discharged from another tunicate. The egg is covered with a membrane which rises into papillæ, giving it the appearance of a chestnut bur made of glass and with a few blunt spines. It develops into a little tadpole-shaped

larva with large rounded head, and lash-like tail. The larva usually breaks through the egg membrane and swims through the water, avoiding the light. Soon, however, it settles down, and becomes fast to the bottom by means of the adhesive slime of its body. Often it becomes fastened by the tail, but occasionally by its head or some other part of the body. The little creature then struggles vainly to free itself for a time, but soon the tail becomes absorbed, the nervous system degenerates and the animal becomes a *Ciona*, fixed for life to one spot, and in its adult state no one would suppose that it was in reality a vertebrate.

Molgula manhattensis, Fig. 119. This is found under stones, etc., below low tide level from Maine to the Carolinas. The body is about one inch in diameter, rounded in outline and usually covered more or less with particles of sand and detritus. In color it is dull olive green. Two long tapering spouts project upward, the uppermost being for the admission, and the lower for the discharge of water which passes through the gills. Altogether the creature presents the appearance of the water bottles made of skin, such as are still used in the Orient, and indeed the name ascidian signifies a little water skin. The eggs are laid a little before daybreak during the summer months, and the larvæ develop in a few hours into little tadpoles within the egg membrane, and finally change into fixed tunicates without being set free from the egg membrane.

Fig. 119; MOLGULA MANHATTENSIS. Woods Holl, Mass.

This species may often be seen in the New York Aquarium, where colonies of volunteer growth attach themselves to the rocky linings of the tanks, and attain full growth in about six weeks.

The Star-Spangled Jelly, *(Botryllus gouldii).* This compound ascidian ranges from New Jersey to Maine, and is very abundant late in summer upon eel grass. It forms smooth, thick, gelatinous expansions of various colors, such as gray-green, dull yellow, brown, purple, or spotted with white. The whole surface appears as if

spangled with stars, outlined usually in brighter color than the general surface of the jelly-like mass. Careful examination shows that each "star" is composed of a half dozen or more mouth openings ranged around a central opening which serves as a common vent. Water is drawn in through the mouth openings and discharged through the vent together with waste products. The minute larvæ are tadpole-like in appearance and swim toward the light. Finally they become fastened by means of their slime to some solid object, and if in a situation suitable for growth they develop into a gelatinous expansion composed of numerous aggregated ascidians all derived by a process of budding from the original larva.

In common with *Molgula*, this species often colonizes in the tanks of the New York Aquarium, the larvæ being pumped in with the sea-water from the harbor.

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These references are, in so far as possible, to works in the English language wherein one may find a more elaborate description than is possible in this little book. They usually refer to the best published drawings, or figures, of the several species. As a rule, the following references relate to species only. References to literature concerning families and orders will be found throughout the text.

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